DOCUMENT RESUME

ED 259 131 CE 041 755

TITLE	Metal Working and Welding Operations.
INSTITUTION	Marine Corps Inst., Washington, DC.
REPORT NO	MCI-13.32
PUB DATE	22 Apr 83
NOTE	213p.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051)
EDRS PRICE	MF01/PC09 Plus Postage.
DESCRIPTORS	Correspondence Study; *Equipment Maintenance; *Equipment Utilization; Hand Tools; Independent Study; Machine Tools; Metals; *Metal Working; Military Personnel; *Military Training; Postsecondary Education; *Trade and Industrial Education; *Welding

ABSTRACT

This student guide, one of a series of correspondence training courses designed to improve the job performance of members of the Marine Corps, deals with the skills needed by metal workers and welders. Addressed in the six individual units of the course are the following topics: weldable metals and their alloys, arc welding, gas welding, metalworking machines and tools, repair of equipment and interpretation of welding symbols, and welding symbols. Each unit contains a general objective, a series of work units addressing different subobjectives, study questions, and answers to the study questions. (MN)

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MARINE CORPS INSTITUTE, MARINE BARRACKS
BOX 1775
ARLINGTON, VA. 22222

13.32f
22 Apr 1983

1. ORIGIN

MCI course 13.32f, Metalworking and Welding Operations, has been prepared by the Marine Corps Institute.

2. APPLICABILITY

This course is for instructional purposes only.

JMD Holladay
J. M. D. HOLLADAY
Lieutenant Colonel, U. S. Marine Corps
Deputy Director

INFORMATION

FOR

MCI STUDENTS

Welcome to the Marine Corps Institute training program. Your interest in self-improvement and increased professional competence is commendable.

Information is provided below to assist you in completing the course. Please read this guidance before proceeding with your studies.

1. MATERIALS

Check your course materials. You should have all the materials listed in the "Course Introduction." In addition you should have an envelope to mail your review lesson back to MCI for grading unless your review lesson answer sheet is of the self-mailing type. If your answer sheet is the pre-printed type, check to see that your name, rank, and social security number are correct. Check closely, your MCI records are kept on a computer and any discrepancy in the above information may cause your subsequent activity to go unrecorded. You may correct the information directly on the answer sheet. If you did not receive all your materials, notify your training NCO. If you are not attached to a Marine Corps unit, request them through the Hotline (autovon 288-4175 or commercial 202-433-4175).

2. LESSON SUBMISSION

The self-graded exercises contained in your course are not to be returned to MCI. Only the completed review lesson answer sheet should be mailed to MCI. The answer sheet is to be completed and mailed only after you have finished all of the study units in the course booklet. The review lesson has been designed to prepare you for the final examination.

It is important that you provide the required information at the bottom of your review lesson answer sheet if it does not have your name and address printed on it. In courses in which the work is submitted on blank paper or printed forms, identify each sheet in the following manner:

DOE, John J. Sgt 332-11-9999
08.4g, Forward Observation
Review Lesson
Military or office address
(RUC number, if available)

Submit your review lesson on the answer sheet and/or forms provided. Complete all blocks and follow the directions on the answer sheet for mailing. Otherwise, your answer sheet may be delayed or lost. If you have to interrupt your studies for any reason and find that you cannot complete your course in one year, you may request a single six month extension by contacting your training NCO, at least one month prior to your course completion deadline date. If you are not attached to a Marine Corps unit you may make this request by letter. Your commanding officer is notified monthly of your status through the monthly Unit Activity Report. In the event of difficulty, contact your training NCO or MCI immediately.

3. MAIL-TIME DELAY

Presented below are the mail-time delays that you may experience between the mailing of your review lesson and its return to you.

	TURNAROUND MAIL TIME	MCI PROCESSING TIME	TOTAL NUMBER DAYS
EAST COAST	16	5	21
WEST COAST	16	5	21
FPO NEW YORK	18	5	23
FPO SAN FRANCISCO	22	5	27

You may also experience a short delay in receiving your final examination due to administrative screening required at MCI.

4. GRADING SYSTEM

LESSONS			EXAMS	
GRADE	PERCENT	MEANING	GRADE	PERCENT
A	94-100	EXCELLENT	A	94-100
B	86-93	ABOVE AVERAGE	B	86-93
C	78-85	AVERAGE	C	78-85
D	70-77	BELOW AVERAGE	D	65-77
NL	BELOW 70	FAILING	F	BELOW 65

You will receive a percentage grade for your review lesson and for the final examination. A review lesson which receives a score below 70 is given a grade of NL (no lesson). It must be resubmitted and PASSED before you will receive an examination. The grade attained on the final exam is your course grade, unless you fail your first exam. Those who fail their first exam will be sent an alternate exam in which the highest grade possible is 65%. Failure of the alternate will result in failure of the course.

5. FINAL EXAMINATION

ACTIVE DUTY PERSONNEL: When you pass your REVIEW LESSON, your examination will be mailed automatically to your commanding officer. The administration of MCI final examinations must be supervised by a commissioned or warrant officer or a staff NCO.

OTHER PERSONNEL: Your examination may be administered and supervised by your supervisor.

6. COMPLETION CERTIFICATE

The completion certificate will be mailed to your commanding officer and your official records will be updated automatically. For non Marines, your completion certificate is mailed to your supervisor.

7. RESERVE RETIREMENT CREDITS

Reserve retirement credits are awarded to inactive duty personnel only. Credits awarded for each course are listed in the "Course Introduction." Credits are only awarded upon successful completion of the course. Reserve retirement credits are not awarded for MCI study performed during drill periods if credits are also awarded for drill attendance.

8. DISENROLLMENT

Only your commanding officer can request your disenrollment from an MCI course. However, an automatic disenrollment occurs if the course is not completed (including the final exam) by the time you reach the CCD (course completion deadline) or the ACCD (adjusted course completion deadline) date. This action will adversely affect the unit's completion rate.

9. ASSISTANCE

Consult your training NCO if you have questions concerning course content. Should he/she be unable to assist you, MCI is ready to help you whenever you need it. Please use the Student Course Content Assistance Request Form (ISD-1) attached to the end of your course booklet or call one of the AUTOVON telephone numbers listed below for the appropriate course writer section.

PERSONNEL/ADMINISTRATION	288-3259
COMMUNICATIONS/ELECTRONICS/AVIATION	
NBC/INTELLIGENCE	288-3604
INFANTRY	288-3611
ENGINEER/MOTOR TRANSPORT	288-2275
SUPPLY/FOOD SERVICES/FISCAL	288-2285
TANKS/ARTILLERY/INFANTRY WEAPONS REPAIR	
LOGISTICS/EMBARKATION/MAINTENANCE MANAGEMENT/ ASSAULT AMPHIBIAN VEHICLES	288-2290

For administrative problems use the UAR or call the MCI HOTLINE: 288-4175.

For commercial phone lines, use area code 202 and prefix 433 instead of 288.

PREFACE

Metalworking and Welding Operations has been designed to provide metalworkers, machinists, and welders, MOS's 1316, 2161, and 3513, sergeants and below, with a source of study material on the operation and maintenance of welding equipment and sheet-metal machines used in the Marine Corps. The course provides broad coverage of the welding processes and identification and heat treatment of metals and their alloys. The course also provides coverage on repair and restoration of damaged sheet metal and Marine Corps equipment.

SOURCE MATERIALS

NAVPERS 10645-D	Construction Mechanic 1 & C, Department of the Navy, Bureau of Naval Personnel, 1970
NAVPERS 10308-B	Structural Mechanic S 3 & 2, Department of the Navy, Bureau of Naval Personnel, 1969
TM 5-4940-201-12	Shop Equipment, Organizational Repair, Light Truck Mounted, 1962
TM 5-4940-209-12	Shop Equipment, General Purpose Repair, Semitrailer Mounted; Set No. 1, 1962
TM 9-237/TO 34W4-1-5	Welding Theory and Application, Nov 67
TM 9-243	Use and Care of Handtools and Measuring Devices, 1960
TM 04055A-15	Welding Set, Arc, Trailer Mounted, Model LM-62, 1962
TM 04055B-15	Welding Machine Arc LM62a, Apr 70
SL-4-04055A	Welding Machine, Arc, Model LM-62, 1963
SL-4-04076A	Welding Machine, Hard-Surfacing, Model HSM-62, 1963

Course Introduction

METALWORKING AND WELDING OPERATIONS is a basic course of particular value to Marines working in or towards the MOS's of 1316, 2161, and 3513. In addition to the fundamental subject matter of the course, there are instructions on identification of metals and their alloys; electric arc welding; welding with gases; metalworking machines and tools; welding equipment and welding procedures used in the Marine Corps.

ADMINISTRATIVE INFORMATION

ORDER OF STUDIES

Study Unit Number	Study Hours	Subject Matter
1	3	Weldable Metals and Their Alloys
2	4	Arc Welding Process
3	3	Gas Welding Process
4	3	Metalworking Machines, Tools
5	2	Repairing Equipment and Interpreting Welding Symbols
6	2	Welding Symbols
	2	REVIEW LESSON
	2	FINAL EXAMINATION
	21	

RESERVE RETIREMENT CREDITS:	7
EXAMINATION:	Supervised final examination without textbook or notes; time limit, 2 hours
MATERIALS:	MCI 13.32f, Metalworking and Welding Operations. Review lesson and answer sheet.
RETURN OF MATERIALS:	Students who successfully complete this course are permitted to keep the course materials. Students disenrolled for inactivity or at the request of their commanding officer will return all course materials.

HOW TO TAKE THIS COURSE

This course contains 6 study units. Each study unit begins with a general objective that is a statement of what you should learn from the study unit. The study units are divided into numbered work units, each presenting one or more specific objectives. Read the objective(s) and then the work unit text. At the end of the work unit text are study questions that you should be able to answer without referring to the text of the work unit. After answering the questions, check your answers against the correct ones listed at the end of the study unit. If you miss any of the questions, you should restudy the text of the work unit until you understand the correct responses. When you have mastered one study unit, move on to the next. After you have completed all study units, complete the review lesson and take it to your training officer or NCO for mailing to MCI. MCI will mail the final examination to your training officer or NCO when you pass the review lesson.

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Section I. Basic welding processes, characteristics, and compositions of metal and their alloys.

	Work Unit	Page
Methods of welding	1-1	1-1
Characteristics of metals and alloys	1-2	1-2
Composition of ferrous metals	1-3	1-4
Composition of nonferrous metals and alloys	1-4	1-7

Section II. Identification of metals

	Work Unit	Page
SAE classification of steel	1-5	1-8
Appearance of metals	1-6	1-9
Fracture tests of metals	1-7	1-11
Grinding wheel test of metals	1-8	1-12
Torch test of metals	1-9	1-14

Section III. Heat-treatment of steel.

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Heat-treating steps	1-11	1-16
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Forms of heat-treatment	1-13	1-19
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Arc-welding machines	2-4	2-24
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Cutting metals with oxyacetylene	3-4	3-13
Welding equipment troubleshooting	3-5	3-24
Inert-gas arc-welding	3-6	3-27

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Special tools	4-2	4-4
Sheet-metal forming machines	4-3	4-10
Sheet-metal layout	4-4	4-18

Study Unit 5. EQUIPMENT REPAIR

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Elements of a welding symbol	6-1	6-1
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MARINE CORPS INSTITUTE

STUDY GUIDE

Welcome to the Marine Corps Institute correspondence training program. By enrolling in this course, you have shown a desire to improve the skills you need for effective job performance, and MCI has provided materials to help you achieve your goal. Now all you need is to develop your own method for using these materials to best advantage.

The following guidelines present a four-part approach to completing your MCI course successfully:

1. Make a "reconnaissance" of your materials;
2. Plan your study time and choose a good study environment;
3. Study thoroughly and systematically;
4. Prepare for the final exam.

I. MAKE A "RECONNAISSANCE" OF YOUR MATERIALS

Begin with a look at the course introduction page. Read the COURSE INTRODUCTION to get the "big picture" of the course. Then read the MATERIALS section near the bottom of the page to find out which text(s) and study aids you should have received with the course. If any of the listed materials are missing, see Information for MCI Students to find out how to get them. If you have everything that is listed, you are ready to "reconnoiter" your MCI course.

Read through the table(s) of contents of your text(s). Note the various subjects covered in the course and the order in which they are taught. Leaf through the text(s) and look at the illustrations. Read a few work unit questions to get an idea of the types that are asked. If MCI provides other study aids, such as a slide rule or a plotting board, familiarize yourself with them. Now, get down to specifics!

II. PLAN YOUR STUDY TIME AND CHOOSE A GOOD STUDY ENVIRONMENT

From looking over the course materials, you should have some idea of how much study you will need to complete this course. But "some idea" is not enough. You need to work up a personal study plan; the following steps should give you some help.

Ⓐ Get a calendar and mark those days of the week when you have time free for study. Two study periods per week, each lasting 1 to 3 hours, are suggested for completing the minimum two study units required each month by MCI. Of course, work and other schedules are not the same for everyone. The important thing is that you schedule a regular time for study on the same days of each week.

Ⓑ Read the course introduction page again. The section marked ORDER OF STUDIES tells you the number of study units in the course and the approximate number of study hours you will need to complete each study unit. Plug these study hours into your schedule. For example, if you set aside two 2-hour study periods each week and the ORDER OF STUDIES estimates 2 study hours for your first study unit, you could easily schedule and complete the first study unit in one study period. On your calendar you would mark "Study Unit 1" on the appropriate day. Suppose that the second study unit of your course requires 3 study hours. In that case, you would divide the study unit in half and work on each half during a separate study period. You would mark your calendar accordingly. Indicate on your calendar exactly when you plan to work on each study unit for the entire course. Do not forget to schedule one or two study periods to prepare for the final exam.

Ⓒ Stick to your schedule.

Besides planning your study time, you should also choose a study environment that is right for you. Most people need a quiet place for study, like a library or a reading lounge; other people study better where there is background music; still others prefer to study out-of-doors. You must choose your study environment carefully so that it fits your individual needs.

III. STUDY THOROUGHLY AND SYSTEMATICALLY

Armed with a workable schedule and situated in a good study environment you are now ready to attack your course study unit by study unit. To begin, turn to the first page of study unit 1. On this page you will find the study unit objective, a statement of what you should be able to do after completing the study unit.

DO NOT begin by reading the work unit questions and flipping through the text for answers. If you do so, you will prepare to fail, not pass, the final exam. Instead, proceed as follows:

Ⓐ Read the objective for the first work unit and then read the work unit text carefully. Make notes on the ideas you feel are important.

Ⓑ Without referring to the text, answer the questions at the end of the work unit.

Ⓒ Check your answers against the correct ones listed at the end of the study unit.

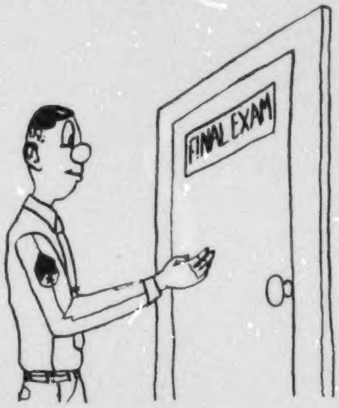
Ⓓ If you miss any of the questions, restudy the work unit until you understand the correct response.

Ⓔ Go on to the next work unit and repeat steps Ⓐ through Ⓓ until you have completed all the work units in the study unit.

Follow the same procedure for each study unit of the course. If you have problems with the text or work unit questions that you cannot solve on your own, ask your section OIC or NCOIC for help. If he cannot aid you, request assistance from MCI on the Student Course Content Assistance Request included with this course.

When you have finished all the study units, complete the course review lesson. Try to answer each question without the aid of reference materials. However, if you do not know an answer, look it up. When you have finished the lesson, take it to your training officer or NCO for mailing to MCI. MCI will grade it and send you a feedback sheet listing course references for any questions that you miss.

IV. PREPARE FOR THE FINAL EXAM



How do you prepare for the final exam? Follow these four steps:

Ⓐ Review each study unit objective as a summary of what was taught in the course.

Ⓑ Reread all portions of the text that you found particularly difficult.

Ⓒ Review all the work unit questions, paying special attention to those you missed the first time around.

Ⓓ Study the course review lesson, paying particular attention to the questions you missed.

If you follow these simple steps, you should do well on the final. GOOD LUCK!

STUDY UNIT 1

WELDABLE METALS AND THEIR ALLOYS

STUDY UNIT OBJECTIVE: UPON SUCCESSFUL COMPLETION OF THIS STUDY UNIT, YOU WILL IDENTIFY THE BASIC WELDING PROCESSES AND THE CHARACTERISTICS AND COMPOSITIONS OF METALS. IN ADDITION, YOU WILL IDENTIFY THE METHODS USED FOR METAL IDENTIFICATION, THE HEAT-TREATING PROCESSES OF STEEL AND RELATED EQUIPMENT.

To perform duties as a metal worker, you must have a working knowledge of metals, their classification, properties, heat-treatment, and welding processes. You must become familiar with the ever-growing family of metals and alloys. The welding process is one of the principal means by which metals are joined. It is a fast, efficient, and economical operation that produces dependable results. Of the many methods of welding metals, the ones that you will come in contact with the most will be the gas and arc methods; therefore, only these methods will be discussed.

Section I. BASIC WELDING PROCESSES, CHARACTERISTICS, AND COMPOSITIONS OF METALS AND THEIR ALLOYS

Work Unit 1-1. METHODS OF WELDING

IDENTIFY THE TWO WELDING METHODS.

Gas welding. Your principal duty in gas welding is to control and direct the heat on the edges of the metals to be welded and to add a suitable filler material to the pool of molten metal. The intense heat obtained in this process comes from the combustion of gases, usually a mixture of oxygen and acetylene. This method is commonly referred to as oxyacetylene welding.

Electric welding. In this field of welding the two processes most commonly used are the resistance and the electric arc methods. Since the resistance method is mostly used in production line manufacturing of products, only a brief explanation of how it works is necessary. In this method of welding, the work is placed in the path of a high-amperage current, and the heat required for the welding is generated by the resistance of the metals contact between the work pieces to the passage of the current. In other words, if two pieces of metal are placed between conductors (electrodes) for a high-amperage low-voltage current, the metals will become semimolten if the current is stopped before the pressure is released, thus allowing these metals to cool and return to a solid state with solid strength. The most common method of electric welding and the one which you will be most interested in is electric arc. This is the process of fuzing two metals together under heat liberated in an arc stream and depositing a filler metal from the tip of an electrode into the molten pool of metal. Mixing of the filler metal with the molten metal produces a strong and dependable weld. A new field of arc welding which produces better welds is the gas-shielded process. In this welding process, both the arc and the weld are shielded by an umbrella of inert gas that has no active chemical properties. The umbrella or shield of gas keeps atmospheric contamination away from the arc stream and the molten pool of metal. These methods, more commonly known as Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG) welding, produce more solid welds.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Identify the two commonly used methods of welding.

a. TIG and MIG	c. Gas and Electric
b. Gas and TIG	d. MIG and Electric

2. State the principal duty in gas welding.

____
____
____
____

3. The process of fuzing two metals together under heat liberated in an arc and of despositing a filler metal from the tip of an electrode into a molten pool of metal is known as __________ welding.

a. electric arc	c. MIG
b. oxyacetylene	d. TIG

4. List two types of gas shielded welding.

a. ______________________________________
b. ______________________________________

Work Unit 1-2. CHARACTERISTICS OF METALS AND ALLOYS

NAME AND DEFINE THE TWO PROPERTIES OF METAL.

To become an efficient metalworker, you must know the properties of metals. This knowledge will aid you to properly weld and work the metals. Everything in nature is made of one or more elements. An element is one of the building blocks with which nature builds more complicated substances we call compounds. Compounds are always composed of two or more elements. For a given compound, these elements are combined in definite fixed proportions. For example, water contains two parts of hydrogen and one of oxygen (H_2O). Physical properties are metal properties determined by chemical compositions which cannot be changed by heat-treatment. They involve color, luster, weight, electrical conductivity, and thermal conductivity. Identification and possible use of metals and alloys can be determined from their physical properties. The characteristics of a metal to resist deformation caused by external forces are called mechanical properties. They are many, and several are listed below with their definition.

Hardness. The resistance of a substance to indentation or penetration.

Wear resistance. The ability of a substance to withstand the cutting or abrasive action generated by the sliding motion between two surfaces that are under pressure

Tensile strength (fig 1-1). The maximum stress that a substance will develop under a slowly applied load, stated in pounds per square inch (psi).

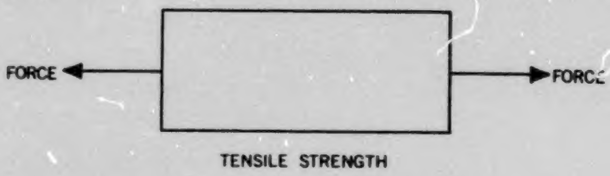


Fig 1-1. Tensile strength.

Stress (fig 1-2). The reaction of a substance to an externally applied force.

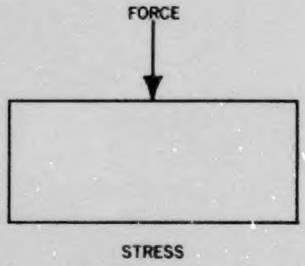


Fig 1-2. Stress.

Strain (fig 1-3). The change in length per unit of length of a material that is subject to stress.

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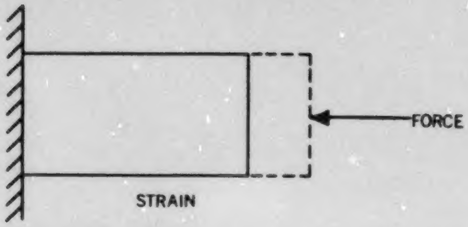

Fig 1-3. Strain.

Corrosion resistance. The ability of a metal to withstand chemical or electrochemical action by atmosphere, moisture, or other agents.

Shear strength (fig 1-4). The resistance to a force acting in a tangential manner tending to cause particles of a body to slide over each other.

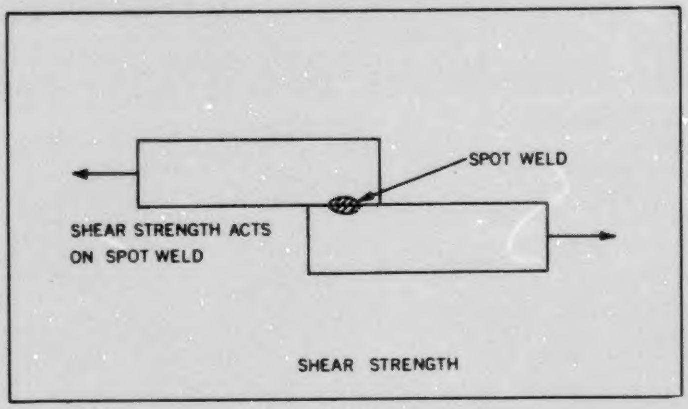

Fig 1-4. Shear strength acts on spot weld.

Toughness. That property of a metal which enables it to withstand shock, endure strains and stresses, and be deformed without breaking.

Machinability. The ease with which stock metal is turned, planed, milled, or otherwise shaped in the machine shop. Proper heat-treatment improves this property.

Ductility. The property of metal which makes it capable of being drawn, stamped, or hammered out thin; in other words, easy to work.

EXERCISE: Complete the exercise below and check your responses against those listed at the end of this study unit.

Name the two properties of metal and define each.

1.

2.

Work Unit 1-3. COMPOSITION OF FERROUS METALS

IDENTIFY CHARACTERISTICS OF THE FOUR IRON METALS.

IDENTIFY THE CHARACTERISTICS OF PLAIN CARBON STEELS.

LIST THE SEVEN ALLOYS OF STEEL

Metals and alloys are both called metals; they both have metallic properties. A pure metal is usually defined as an element that, when solid, has a crystalline structure, is usually opaque, is a good conductor of heat, and has a peculiar luster when fractured. Some examples of pure metal are iron, aluminum, zinc, lead, copper, and magnesium. Pure metals are always elements. An alloy, on the other hand, is a substance that has metallic properties and is composed of two or more elements, at least one of which is a metal. Examples of alloys are steel, bronze, and heat-treatable aluminum. The metals with which you will work are divided into two general classifications: ferrous and nonferrous. A ferrous metal is composed mostly of iron; for example, pig iron, cast iron, wrought iron, carbon steels, and the various alloy steels. All other metals are nonferrous. You are probably familiar with many nonferrous metals, such as gold, silver, lead, zinc, aluminum, copper, and tin.

a. Ferrous metals. Before iron and steel products can be manufactured, you must mine and then convert it to metallic iron by melting it in a blast furnace in the presence of coke and limestone. The chemical and physical reaction which takes place in this process reduces the ore to molten iron. This iron is drawn from the bottom of the furnace and poured into molds to form shapes of convenient size, known as "pigs." Pig iron is composed of about 93% iron, 3% to 5% carbon, and varying amounts of other elements. Pigs are used in the manufacture of cast iron.

(1) Gray cast iron. This type of cast iron contains 90% to 94% pure iron and varying proportions of carbon, manganese, phosphorus, silicon, and sulfur. It is very fluid when in the form of molten and it solidifies slowly; therefore, castings of intricate designs can be easily made with this metal. If weight and rigidity are required without very great strength, use gray cast. Usually it is found in the blocks of automobile engines, pump bodies, gears, pulleys, and machine frames.

(2) White cast iron. It is produced by casting against metal chills (special blocks used to dissipate heat). This procedure causes the free carbon in the gray cast iron to combine with the iron. The result is a very hard and brittle iron with no free carbon. This metal can be used when hardness and resistance to wear are essential, such as for treads on freight car wheels. It is not recommended to weld white cast iron.

(3) Malleable cast iron. By heating white cast iron to about 1,650°F, by holding it at this temperature for several hours or even days, and by cooling it slowly, we have what is known as a malleable cast iron. This type of cast can be bent without breaking, and it will withstand shock. Hard-wearing handtools, pipe fittings, and automotive parts are usually made of malleable cast iron.

(4) Wrought iron. When pig iron is further refined in a puddling furnace, still more of its impurities are removed. The resulting product is wrought iron. The chemical analysis of wrought iron and mild steel are practically the same; the elements of both metals are very similar. In iron, the carbon content is considered an impurity, whereas in steel the carbon content is considered an alloying element. An alloying element produces a desired or wanted effect. Also, the differences in the process of manufacturing cause the difference in the properties of the two metals. Wrought iron is made by a process of puddling, squeezing, and rolling. This introduces slag into the iron and gives it a fibrous internal structure similar to that of a piece of wood. This structure is responsible for its workability and resistance to corrosion. It is used for crane hooks, bolts, piping, rivets, and nails. Steels, on the other hand, are made by a process of smelting, decarburizing, deoxidizing, solidifying, and rolling. The decarburizing removes the excess carbon, and deoxidizing takes out other impurities by the use of manganese. During most of its manufacture, steel is in molten condition. When it is poured into ingots, it solidifies into a granular structure. It is then sent to rolling mills to be formed into shapes. As mentioned before, on the surface mild steels and wrought iron look the same; the internal structure is the difference between the two. A further look at different types of steels that you will come into contact with will be presented below.

b. Plain carbon steels. The carbon which is dissolved or combined in these steels may be present in various amounts depending on the type of steel, but in any case will not exceed 1.70%. Carbon steels may also contain other elements such as manganese, which is added to increase the hardness and toughness of the metal by reducing impurities, and silicon, which frees the metal from pockets and blowholes (pockets of gas trapped in solidifying molten metals). Sulfur and phosphorous are considered impurities, but in some cases sulfur is added to increase the machinability of the metal.

(1) Low-carbon steels. These are steels containing up 0.25% carbon which are usually used when structural strength is of no great importance. These steels are easily welded.

(2) Medium-carbon steels. These steels have a carbon content ranging from 0.25 to 0.45%. When these steels are welded, the zone in the vicinity of the weld which has been heated to its critical temperature will harden if cooled rapidly. This hardening can be avoided by preheating the metal to between 300° and 500°F, depending on the thickness of the metal and its carbon content before welding, and also by heating to a temperature below the critical range, usually to about 1,110°F and allowing it to cool slowly, thereby removing internal stresses which developed during the welding operation. This is known as stress-relieving.

(3) High-carbon steels. These steels have a carbon content exceeding 0.45%. They are very difficult to weld because of the hardening effect of the heating in the vicinity of the weld. High-carbon steel must be preheated to at least 500°F before welding, and stress-relieved at 1,100° to 1,250°F after welding.

(4) Tool steels. Tool steels normally gave a carbon content exceeding 0.60%. They are relatively hard to weld and require slow preheating up to 1,000°F. Stress-relieving similar to that required for high-carbon steels and subsequent reheat-treatment, must be performed immediately after welding.

(5) Copper-bearing steels. These steels are generally of the low-carbon type and contain 0.20% to 0.50% copper. They have the welding characteristics of low-carbon steels.

c. Alloy steels. The principal metals used as alloys in steel are chromium, manganese, molybdenum, nickel, tungsten, and vanadium. Silicon is combined with some of these metals to obtain certain desired characteristics. Many of the alloy steels contain several alloying elements, and all those listed are weldable. The alloy steels with the simplest composition are generally easiest to handle.

(1) Chromium. This is used as an alloying element in low-carbon steels to increase corrosion resistance, hardenability, and resistance to shock. It also imparts high strength with little loss in ductility. All corrosion-resistant steels contain chromium and nickel.

(2) Manganese. Manganese is used in steel to produce greater toughness and wear resistance, and to promote easier hot rolling and forging. Increasing manganese in steel decreases the weldability of the final product.

(3) Molybdenum. Addition of this alloy to steel increases the hardenability, which is the depth of hardening possible through heat-treatment. The impact-fatigue property of a steel is improved with up to 0.60% molybdenum. Above 0.60%, this property is impaired, but the wear resistance is improved when the content is raised to above 0.75%. Molybdenum is sometimes combined with chromium or nickel or both. Molybdenum is sometimes combined with chromium, tungsten, or venadium to obtain desireable properties.

(4) Nickel. Toughness, ductility, and strength of steel are increased by adding nickel. It lowers the hardening temperature so that an oil quench rather than a water quench can be used for hardening. The addition of 25% to 35% nickel to steel develops high resistance to corrosion.

(5) Tungsten. This metal alloy enables hardened steel to retain its hardness and strength even when heated to 1,150°F. For this reason cutting tools made of tungsten-steel can be used at a speed or cutting depth where friction would raise the temperature to 1,000°F without impairing the effectiveness of the tool. Tungsten is frequently used in conjunction with other alloying elements, such as chromium and vanadium.

(6) Titanium and columbium. These elements are used as an additional alloying agent in low-carbon content, corrosion-resistant steel that also contains chromium and nickel. They support resistance to intergranular corrosion after the metal is subjected to high temperatures for a prolonged period.

(7) Vanadium. The primary purpose of vanadium is to increase the hardenability and strength of the steel and decrease the grain size. It is also added during the manufacturing of steel to remove oxygen.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The cast iron used in making automobile engines is

a. gray.
b. wrought.
c. white.
d. malleable.

2. The cast iron not recommended for welding is

a. gray.
b. wrought.
c. white.
d. malleable.

3. The cast iron which can be bent without breaking is

a. gray.
b. wrought.
c. white.
d. malleable.

4. The cast iron used to make nails, rivets, and crane hooks is

a. gray.
b. wrought.
c. white.
d. malleable.

5. The maximum amount of carbon found in plain carbon steel is

a. 0.25%
b. 0.45%
c. 1.70%
d. 1.90%

6. When structural strength is of no great importance, _________ _________ is used.

a. copper-bearing
b. low carbon
c. medium carbon
d. high carbon

7. The maximum amount of heat required for stress-relieving high-carbon steel is

a. 500°F.
b. 1,000°F.
c. 1,100°F.
d. 1,240°F.

8. The plain carbon steel with a carbon content exceeding 0.60% is

a. low.
b. medium.
c. high.
d. tool.

9. Copper-bearing steel has a copper content of _________ to _________%.

a. 10% to 20%
b. 15% to 30%
c. 0.20% to 0.50%
d. 25% to 55%

10. List the seven alloys of steel.

(1)
(2)
(3)
(4)
(5)
(6)
(7)

Work Unit 1-4. COMPOSITIONS OF NONFERROUS METALS AND ALLOYS

MATCH FIVE OF THE TWELVE NONFERROUS METALS WITH THEIR CHARACTERISTICS.

a. Aluminum. Aluminum, alloyed with magnesium, copper, iron, or other metals, is most commonly used for industrial purposes. The most noticeable characteristics of these alloys are their high strength although their weight is light and they resist corrosion. Most of these alloys in rolled, cast, or extruded form can be welded by the oxyacetylene, resistance, and electric-arc processes.

b. Copper. This metal is commercially available in two major groups: oxygen-bearing copper and oxygen-free copper. The oxygen-bearing copper is of medium strength, ductile, tough, and highly malleable. The oxygen-free copper has the same general characteristics, but the properties are more uniform and the electrical and thermal conductivities are somewhat higher.

c. Copper alloys (brasses). These are copper-zinc alloys with varying percentages of these two metals with corresponding variations in the properties of the brass. Occasionally, as described below, a third or forth alloying metal is added to improve one or more of the mechanical properties. Brasses are produced in three classifications: low, high, and alloy.

(1) Low brasses. These brasses contain 80% to 95% copper and 5% to 20% zinc. They range in color from red through gold, to green-yellows. The low brasses are ductile and malleable at room temperature. They can be cold-worked by such operations as deep drawing, spinning, and stamping.

(2) High brasses. High brasses contain 55% to 80% copper and 20% to 45% zinc. The tensile strength, hardness, and ductility increase as the percentage of zinc increases. Metals suitable for both cold- and hot-working are found in the high brasses.

(3) Alloy brasses. The alloy brasses contain, in addition to zinc, small quantities of tin, manganese, iron, or lead. These alloying agents are added to produce desired properties, such as machinability, resistance to corrosion, and improvement of hot-working properties.

d. Silicon bronze. Copper-silicon alloys (silicon bronze) contain silicon with zinc, tin, manganese, or iron as alloying agents. They have high tensile strength and excellent corrosion resistance and are readily welded, usually by the carbon-arc process.

e. Phosphor bronze. Copper-tin alloys (phosphor bronze) contain tin (1.5% to 10%) as the principal alloying agent, a small quantity of phosphorus as a deoxidizing agent, and small percentages of zinc, manganese, lead, antimony, or iron. These bronzes are tough and hard and have high fatigue resistance.

f. Aluminum bronze. Copper-aluminum alloys (aluminum bronze) contain aluminum as the principal alloying agent with additions of nickel, iron manganese, and silicon in varying low percentages. The working characteristics, hardness, ductility, and other properties of these bronzes are governed by the percentages and type of alloying agents, but all of them resist scaling and oxidation at high temperatures. They are highly resistant to mineral acid attack and corrosion from sea water.

g. Copper-nickel alloys. Copper-nickel alloys are available in three types containing 10%, 20%, and 30% nickel. These alloys have moderately high to high tensile strength, depending on the nickel content. They are moderately hard and quite tough and ductile. They are very resistant to the erosive and corrosive effects of high-velocity sea water, to stress corrosion, and corrosion fatigue.

h. Nickel silver. Nickel is added to copper-zinc alloys (brasses) to lighten their color; the resultant alloys are called "nickel silver." These alloys are of two general types, one type containing 65% or more of copper and nickel combined, the other containing 55% to 60% copper and nickel combined. The first type can be cold-worked by such operations as deepdrawing, stamping, and spinning. The second type is much harder and is not processed by any of the cold-working methods. Gas welding is the preferred process for joining these metals.

i. Copper-beryllium alloys. These alloys usually contain approximately 1.5% to 2.5% beryllium with slight additions of iron, nickel, and silver. When age-hardened, they have very high tensile strength and hardness. They are quite ductile and suitable for cold-working when softened, but they loose their ductility if cold-rolled or case hardened.

j. Magnesium and magnesium alloys.

(1) Magnesium is roughly one-fifth the weight of steel and two-thirds the weight of aluminum. Magnesium is a weldable, white metal with a low melting point and excellent machinability. Commercial magnesium is usually alloyed with various amounts of aluminum, maganese, and zinc to obtain maximum strength and corrosion resistance.

(2) Two alloys, AZ31X and M1, in the form of extrusions, plates, and sheets, are most widely used in applications involving welding. AZ31X contains varying amounts of aluminum, zinc, and manganese for sheets, plates, extruded shapes, and structural sections. M1 contains 1.5% manganese.

k. Nickel and nickel alloys (monel).

(1) Nickel is very ductile, malleable, grayish-white metal. It oxidizes slowly in the presence of moisture and is resistant to corrosive fumes. It is used as an alloying element in the production of certain steels.

(2) Monel is a silver-white metal containing approximately 67% nickel, 28% copper, and small amounts of silicon, manganese, carbon, and sulfur. Some types of this metal contain a small percentage of aluminum. The most important property of monel is its resistance to corrosion.

l. Lead. This is a heavy soft metal, bright white in color when freshly cut, but it oxidizes quickly to a dull gray. Lead is resistant to corrosion from ordinary atmosphere, moisture, and water and is particularly effective against many acids.

EXERCISE: Match the nonferrous metals listed as "1" through "5" in column "A" with the correct characteristic, listed as "a" through "e", in column "B". Check your responses with those listed at the end of this study unit.

Column A	Column B
1. Aluminum	a. Hardness, ductility
2. Copper	b. Weldable, white metal, low melting point, machinable
3. Aluminum bronze	c. Medium strength, ductile, tough, malleable
4. Copper-nickel	d. High strength, light weight, resists corrosion
5. Magnesium	e. Moderately hard, tough, ductile

Section II. IDENTIFICATION OF METALS

Work Unit 1-5. SAE CLASSIFICATION OF STEEL

LIST THE THREE ELEMENTS OF THE SAE NUMERICAL SYSTEM FOR THE CLASSIFICATION OF STEEL.

Originated by the Society of Automotive Engineers (SAE), the numerical index system for the classification of steels has been generally adopted by industry for the identification of steels on drawings and in specifications. In this system, the class to which the steel belongs, the percentage of the predominant alloying agent, and the average carbon content in percent are indicated as described in paragraph 1-4.

The various classes of steel are identified by the first digit of the SAE number as indicated below:

Class	Number
Carbon steels	1
Nickel steels	2
Nickel-chromium steels	3
Molybdenum steels	4
Chromium steels	5
Chromium-vanadium steels	6
Heat-resistant casting alloys	7
Nickel-chromium-molybdenum steels	8
Silicon-manganese steels and nickel-chromium-molybdenum steels	9

The first digit indicates the type to which the steel belongs; thus, 1 indicates a carbon steel, 2, a nickel steel, and 3, a nickel-chromium steel. In the case of simple alloy steels, the second digit generally indicates the approximate percentage of the predominant alloying element. Usually the last two or three digits indicate the average carbon content in hundredths of 1%. Thus, 2340 indicates a nickel steel (indicated by the first digit-2) of approximately 3% nickel (indicated by the second digit-3) and 0.40% carbon (indicated by the last two digits). In some instances, it has been necessary to depart from this system of identifying the composition of the steel by varying the second and third digits of the number. This is indicated by the numbers selected for several corrosion and heat-resisting alloys and triple alloy steels that can be found in the most recent SAE handbook.

EXERCISE: Answer the following questions and check your responses with those listed at the end of this study unit.

1. List the three elements of the SAE numerical index system.

    a. ______________________________
    b. ______________________________
    c. ______________________________

2. A metal with a classification number of 2542 indicates it is made of what type steel?

    a. Nickel
    b. Nickel-chromium
    c. Chromium
    d. Molybdenum steel

3. 2542 indicates steel with a nickel content of __________%.

    a. 4
    b. 5
    c. 6
    d. 7

4. 2542 indicates nickel steel with a carbon content of

    a. 542%.
    b. 52%.
    c. 42%.
    d. 32%.

Work Unit 1-6. APPEARANCE OF METALS

DESCRIBE THE APPEARANCE TEST.

Have you ever dropped a coin on the deck to find out what it was made of? Maybe at that time you didn't know it, but you were testing the metal by the ring it made when it bounced to find out whether it was made of nickel, copper, or silver, or if it were counterfeit. Other tests as simple as this one have been devised to identify metals. You can test by the appearance of the metal, the fracture (chip) test, the grinding wheel (spark) test, and the torch test. Normally bar stock is color-coded on the ends to identify the type of steel. However, suppose the user of the bar, who used it before you, cuts off the end that has the color code, then you will have to resort to other methods to determine the type of material that you have. It is possible to make these tests with little or no equipment, therefore they are convenient and easy to do. As long as you are a metalworker you will be either making or hearing other people make references to metal identification tests, so it is a good idea to know what they are all about.

In the metal workshop or the storage area, identification marks may be destroyed. When this happens, metals must be identified by other means.

Appearance. Frequently metal may be identified by its surface appearance, that is, its color and texture. Examining the outside unfinished surface of a metal is not always sufficient evidence for classifying it, but it does make it possible to classify the metal group, thereby limiting additional tests needed for specific identification. The surface color will put it into a class. The following list may help you to fix in your mind the surface appearance of the more common metals. If color and surface textures are not enough evidence upon which to base your classification, you should then resort to the chip and torch tests.

a. Gray cast iron. The unmachined surfaces are very dull gray and probably somewhat roughened by the sand mold used in casting the part. Unmachined castings may have brighter areas where rough edges have been removed by grinding.

b. Malleable iron. The surface is much like gray cast iron, but the dull gray color is somewhat lighter. It is generally free of sand.

c. Wrought iron. Its appearance is the same as that of rolled low-carbon steel.

d. Low-carbon steels. The appearance of the steel depends on the method of its treatment rather than its composition.

(1) Cast. This steel has a relatively rough, dark-gray surface, except where machined.

(2) Rolled. This steel has fine surface lines running in one direction.

(3) Forged. This steel is usually recognizable because of its shape, hammer marks, or finish.

e. High-carbon steels. The unfinished surface is dark gray and similar to other steels; however, these steels are usually worked to a smoother finish than the less costly low-carbon steels.

f. Steel forgings. The surface is smooth. If forgings have not been finished, fins caused by metal squeezing out between the forging dies will be evident. If finished, the area from which the fins have been removed will be noticeable. These forgings, unless they have been properly cleaned, are covered with a reddish-brown or black scale.

g. Alloy steels. Drop forgings have the same appearance as other drop-forged steels. Many of the alloy steel products are machined all over.

h. Cast steel. The surface is brighter than cast or malleable iron and sometimes contains small depressions similar to a burst bubble.

i. Aluminum. Aluminum is white, very bright when polished, dull when oxidized, and light in weight.

j. Aluminum bronzes. These metals are yellow; but, when polished, they are darker than brass.

k. Brasses and bronzes. The colors of polished brasses and bronzes vary from an almost copper red to yellow, depending on the composition of the metal. They oxidize to various shades of green, brown, and yellow.

l. Copper. Copper is red when polished. It oxidizes to various shades of green.

m. Lead. Lead is white when freshly cut, and it becomes dull gray when exposed to air. It is very soft and heavy.

n. Magnesium. This metal is silver-white and weighs about one-third less than aluminum.

o. Monel metal. Monel metal is light gray which dulls to a darker gray on aging.

p. White metal die castings. These are usually made with alloys of aluminum, lead, magnesium, and tin. Excepting those made of lead or tin, they are light in weight and generally white. The surface is much smoother than that produced by castings made in sand.

EXERCISE: In the space provided below, describe the appearance test. Check your response against the one listed at the end of this study unit.

1.

Work Unit 1-7. FRACTURE TESTS OF METALS

DESCRIBE THE PROCEDURE FOR PERFORMING THE FRACTURE TEST.

Fracture test. The test is made by removing a small amount of material from the sample of metal with a sharp, cold chisel. The material removed will vary from small, broken fragments to a continuous strip. The chip may have smooth, sharp edges, or it may be coarse-grained or fine-grained, or it may have sawlike edges where it has been cut. The size of the chip is important in identifying the metal. The ease with which chipping takes place is important for identification. Examine the chips until you are sure you can recognize them the next time you see them.

a. Gray cast iron. Nick a corner of the gray cast iron with a chisel or hacksaw and break it off by hitting a sharp blow with a hammer. The break will be short and the exposed surface will be dark gray. This color is caused by fine specks of graphite dispersed throughout the metal. Chips raised by a chisel break off as soon as formed.

b. Malleable iron. The central portion of the broken surface is dark gray with a bright steel-like band around the edge, somewhat like a picture frame. Good quality malleable iron is much tougher than cast iron and does not break short when nicked.

c. Wrought iron. Wrought iron can be bent and is quite ductile. When wrought iron is nicked and bent to the breaking point, the break is jagged. This iron has a fibrous structure which can be split in the direction in which the fibers run. It is easily cut with a chisel.

d. Low-carbon steels. The color is bright crystalline. The metal is tough when chipped or nicked.

e. High-carbon steels. These steels are harder and more brittle than low-carbon steels and the fracture is whiter and finer grained.

f. Steel forgings. Forgings may be of low-carbon, high-carbon, or tool steel and the color will vary from bright crystalline to silky gray. When the specimen is nicked, it is harder to break than cast steel and has a finer grain.

g. Alloy steels. Generally, the alloy steels are very fine-grained. Sometimes the fracture has a velvety appearance.

h. Cast steel. The surface of the fractured area is bright crystalline. Steel castings are tough and do not break short. Chips made with a chisel, except manganese steel, curl up. Manganese steel cannot be cut with a chisel.

i. Aluminum. Castings show a bright crystalline structure. Rolled metal shows a bright and smooth surface.

j. Brasses and bronzes. The fractured surface ranges from smooth to crystalline, depending on the composition of the metal and whether it has been cast, forged, or rolled.

k. Aluminum bronzes. The fractured surface is smooth.

l. Copper. It presents a smooth surface that is not crystalline.

m. Lead. It is white and crystalline.

n. Magnesium. The fractured surface is rough and finely granular.

o. Monel metal. The fractured surface is crystalline. Its color is similar to that of nickel.

p. White metal die castings. Its fractured surface is white and somewhat granular.

EXERCISE: In the space provided below, describe the procedure for performing the fracture test. Check your response with the one listed at the end of this study unit.

1.

Work Unit 1-8. GRINDING-WHEEL TESTS OF METAL

DESCRIBE THE GRINDING-WHEEL TEST.

Grinding-wheel test. Various types of iron and steel produce sparks which vary in length, shape, and color when held lightly against a grinding wheel. The sparks given off, or the lack of sparks, assist in identifying the metal. The wheel should be the aluminum oxzide type, hard enough to wear reasonably long, yet soft enough to retain free cutting properties. The peripheral speed should be approximately 4,000 feet per minute in order to produce good, bright sparks. The length of the spark stream, its color, and the type of sparks are what you should look for. There are four fundamental spark forms produced by holding a sample metal against a grinding wheel. In figure 1-5, A. shows shafts, buds, break, and arrow. The arrow or spearhead is characteristic of molybdenum, a metallic element of the chromium group. B. shows shaft and sprigs or sparklers which indicate a high carbon content. D. shows shafts and forks which indicate a low carbon content. The tests should be performed in well-diffused daylight against an ordinary background. In all cases, it is advisable to use standard samples of metals of known composition so that these sparks can be compared with the material under test.

Warning: Nonferrous metals can clog the wheel causing it to overheat and explode, if test is not conducted properly.

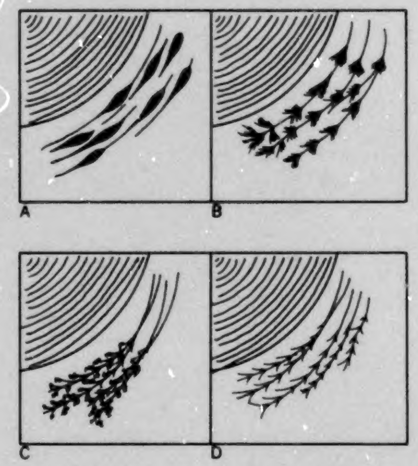

Fig 1-5. Fundamental spark forms.

a. Gray cast iron. A small volume of dull red sparks, that follow a straight line will form close to the wheel. These break up into fine, repeated spurts, which change to straw color.

b. Malleable iron. The outer bright layer gives bright sparks like steel. When the interior is reached, the sparks quickly change to a dull red color near the wheel. These sparks are much like those from cast iron, but are somewhat longer and are present in larger volume.

c. Wrought iron. Straw-colored sparks form near the grinding wheel, and later they change to white forked sparklers near the end of the stream.

d. Steel forgings. The sparks given out are long white streamers. Sparks from high-carbon steel are whiter than those from low-carbon steel.

e. Alloy steels. The various alloy steels produce characteristic sparks both in color and shape. This enables a person, with practice, to identify many of the alloy steels. Some of the more common metals used in alloy steels and their effect on the spark stream are described below.

(1) Chromium. Steels containing 1% to 2% chromium have no outstanding features in the spark test. Chromium in large amounts shortens the length of the spark stream to half of that produced by steel containing no chromium, without appreciably affecting its brightness. Steel containing 14% chromium and no nickel produces sparks similar to those given off by low-carbon steel, but shorter. An 18% chromium, 8% nickel stainless steel alloy produces a spark similar to that of wrought iron, but only half as long. An 18% chromium, 2% carbon steel (chromium die steel) produces a spark similar to that of carbon tool steel, but one-third as long.

(2) Manganese. Steels containing this element produce a spark similar to a carbon spark. A moderate increase in manganese increases the volume of the spark stream and the intensity of the bursts. A steel containing more than a normal amount of manganese will spark in a similar way as that of a high-carbon steel with a lower manganese content. For instance, a steel containing 0.55% carbon and no alloying element will have the same spark characteristics as a steel containing 1.60% to 1.90% manganese.

(3) Molybdenum. Molybdenum has an easily recognizable spark. It appears as an orange spearhead on the end of every carrier line. This element is used as an alloy in conjunction with nickel or chromium or both. Its characteristic spark has a detatched arrowhead similar to that of wrought iron. It can be seen in fairly strong carbon bursts. Molybdenum, substituted for some of the tungsten in high-speed steel, causes the spark streams to turn orange.

(4) Nickel. Nickel gives a characteristic spark identified by tiny blocks of brilliant white lights. This characteristic spark from nickel steel may be the result of the suppressing effort of nickel on the carbon burst. This element is recognized in SAE steels where the carbon content is low and the carbon sparks are not too prominent. The nickel spark is a short, sharply defined flash of brilliant light just before the formation of the fork. The nickel spark is difficult to detect because some nickel-free steels have a similar, but more rounded burst.

(5) Tungsten. This element is easy to detect. It imparts a dull red color to the spark stream near the wheel. It also shortens the spark stream and decreases the size of or completely eliminates the carbon burst. A tungsten steel containing about 10% of this element causes short, curved orange spear points at the ends of the carrier lines of the spark stream; a lower tungsten content causes small, white spear points. The carrier lines may be dull red to orange, depending on other elements present and provided that the tungsten content is not high.

(6) Vanadium. The spark test is not conclusive in this element. The detatched arrow-heads at the ends of the carrier lines are similar to those produced by molybdenum steels.

f. Cast steel. The sparks are much brighter than those from cast iron. Manganese steel gives off sparks that explode, throwing off brilliant sparklers at right angles to the original path of the spark.

g. Aluminum. No sparks are given off.

h. Aluminum bronzes. No sparks are given off.

i. Copper. No sparks are given off.

j. Lead. No sparks are given off.

k. Magnesium. No sparks are given off.

l. Monel metal. It produces short, wavy, orange streaks similar to those given off by nickel.

m. White metal die castings. No sparks are given off.

EXERCISE: In the space provided below, describe the grinding-wheel test. Check your response with the one listed at the end of this study unit.

1.

Work Unit 1-9. TORCH TEST OF METALS

DESCRIBE THE TORCH TEST.

Torch test. Various metals can be identified by using an oxyacetylene torch and by studying the behavior of the metal under the torch. A person may determine the type metal being tested by timing the melting rate, by watching the appearance of the molten metal and slag, and by observing color changes and other manifestations developed by heat.

a. Gray cast iron. A heavy, tough film forms on the surface as it melts. The puddle is quite depressed and very fluid. When the torch flame is raised, the depression in the surface of the puddle disappears instantly. The molten puddle solidifies slowly, and it does not give off sparks.

b. Malleable iron. The molten metal boils under the torch flame. When the flame is withdrawn, the surface will be found full of blowholes. The melted part will cool to a substance very hard and brittle. It is, in fact, white cast iron or chilled iron produced by the melting and comparatively rapid cooling. The outer steel-like shell will give off sparks under the torch, but the center portion will not.

c. Wrought iron. Wrought iron melts quickly, with a slight tendency to spark. The melted iron has a peculiar slag with white lines and a greasy or lily appearance.

d. Low-carbon steels. The steel gives off sparks when melted and, when the flame is removed, solidifies almost instantly.

e. High-carbon steels. The molten metal is brighter than molten low-carbon steel , and the melted surface has a cellular appearance.

f. Steel forgings. Steel forgings spark when melted. The greater the carbon content, the greater the number and brilliance of the sparks.

g. Alloy steels. Steels containing a considerable quantity of chromium display a greenish-colored slag on the weld or puddle when cold. In general, the effects of the torch test depend on the composition of the alloy steel and must be determined by trial and experience.

h. Cast steels. These steels spark when melted and solidify quickly.

i. Aluminum. Aluminum does not show red before melting. It holds its shape until almost molten and then collapses suddenly. A heavy coating of white oxide forms instantly on the molten surface.

j. Aluminum bronzes. The surface is quickly covered with a heavy scum which tends to mix with the molten metal, and it is difficult to remove. Welding of these bronzes is extremely difficult.

k. Brasses and bronzes. True brass contains zinc, which gives off white fumes when melted. Bronzes contain tin, which increases fluidity. Some bronzes contain zinc and will fume, but not as much as brass.

l. Copper. Because of the heat-conducting properties of copper, a larger flame is required to produce fusion than the one required for other metals. Copper melts suddenly and solidifies instantly. Copper alloys, containing small amounts of other metal, melt more quickly and solidify more slowly.

m. Lead. It melts at a very low temperature. The molten metal becomes covered with a thin, dull slag.

n. Magnesium. Magnesium oxidizes rapidly when heated in the air to its melting point. For this reason, as a safety precaution, this metal is melted in an atmosphere free from oxygen. When heated in the open air, it produces an oxide film which is highly refractory and insoluble in the liquid metal.

o. Monel metal. Monel flows clearly without any sparklers, and a heavy black scale forms when cooling.

p. White metal die castings. The melting point is so low that the metal boils under the torch.

EXERCISE: In the space provided below, describe the torch test. Check your response against the one listed at the end of this study unit.

1.

Section III. HEAT-TREATMENT OF STEEL

Work Unit 1-10. HEAT-TREATING PURPOSES

DEFINE HEAT-TREATING.

When the conditions of heating and cooling a metal or an alloy in the solid state are controlled so that certain desired properties are developed, heat-treating is accomplished. When metal is heated and cooled, structural changes take place. By controlling these structural changes, the desired physical properties develop. The use to which a metal is to be put determines the property it will require. A knife blade must be hard and capable of keeping its sharp edge. A chain needs to be tough. The physical properties of metals, such as ductility, machinability, toughness, hardness and tensile strength can be developed through heat-treating. Often one property must be sacrificed to gain another. For example, the harder a metal is made, the less ductile it will be. A material is heat-treated to improve it for the service intended, or to put it in a condition which will make a subsequent operation such as machining, easier to perform.

The reasons for heat-treating are as follows:

a. Relieve stresses produced by forming or welding.

b. Increase hardness and tensile strength.

c. Develop ductility.

d. Induce toughness.

e. Aid machinability.

f. Increase wear resistance.

g. Alter electrical properties.

h. Modify magnetic properties.

i. Refine or coarsen grain structure.

j. Develop a more desirable grain structure.

k. Change the chemical composition of a steel surface as in casehardening.

EXERCISE: In the space provided below, define heat-treating. Check your response with the one listed at the end of this study unit.

1.

Work Unit 1-11. HEAT-TREATING STEPS

LIST THE THREE STEPS IN THE HEAT-TREATING PROCESS OF METAL.

TREATING PROCESS.

a. General. The particular treating process to be used depends on the composition of the metal and the property you want to develop. Some processes not only cause changes in chemical and physical properties, they alter the surface composition of the metal as well. When there is no change in composition, the heat-treating operation involves only heating and cooling, in which the factors of time and temperature are most important. When there is a change in composition, the element surrounding the metal during heating, or during heating and cooling, is equally as important as time and temperature. Those factors must be definitely fixed in advance for the particular composition of the metal and the treatment involved. Methods of treatment which cause no change in composition are true heat-treating operations. These are normalizing, annealing, hardening, and tempering. Carburizing, cyaniding, and nitriding, on the other hand, effect a change in the composition of the metal near the surface, through its absorption of an element during the heat-treatment. Heat-treating must be done under controlled conditions, and an important factor to remember is that, in heat-treating steel, it should never be heated to a temperature close to the melting point. When this occurs, certain elements in the metal are burned out (oxidized), and the steel in this condition usually cannot be restored by subsequent heat-treatment. This means that the time, temperature, and manner of heating and cooling must be controlled.

b. Heat-treating steps. Heat-treatment involves three steps: get the metal hot, hold the heat, and cool it.

(1) Get the metal hot. Heating may be done in numerous ways, depending on the equipment available. Large shops may have salt and lead baths, controlled-atmosphere electric furnaces, or induction furnaces. A small shop such as the "village smithy" may have only a forge or a torch. On occasion, you may be called upon to harden and temper a chisel with no means of applying heat other than an oxyacetylene welding torch; at other times you may have plenty of equipment. In addition to your torch, you may have an oil-fired forge, a medium-temperature electric preheat furnace (annealing furnace), and high-temperature hardening furnace. Both of these furnaces are equipped with controllers, with which you can regulate the speed of heating and maintain any desired temperature within range of the furnace. In addition, these furnaces are equipped with a device for controlling the atmosphere inside them. The controls may be set for a specific atmosphere, such as carburizing, oxidizing, or neutral, which minimizes the possibility of scaling, decarburizing, or burning of the metal.

(2) Hold the metal heat. Did you ever notice what happens to a baked potato? It is subjected to heat which warms the outside and then cooks through to the center, changing the properties and cooking of the potato. In a similar manner, except that the degree of heat may range as high as 2,400°F for some alloys, metal is heated and brought to temperature in the heat-treating operation. The important point to remember in heating is the uniformity with which the metal is brought up to temperature. Don't forget that thin sections heat faster than thick ones, just as little potatoes cook faster than big ones. When you use a salt or lead bath, or an electric or oil-fired furnace, you are assured of getting uniform heating. If you don't have this equipment and have to rely on your torch, or at best a forge, you'll have to be careful that the stock is being heated uniformly. Just getting the metal hot, however, is not going to do the whole job. Many operations in heat-treating specify that the temperature must be held constant for a specified length of time. This is called holding or soaking. When you bake a potato, you can stick it with a fork to see if it is done all the way through.

If it is not, you bake it some more. Of course, you can't stick a fork in a piece of metal to see if it has heated through, so you have to allow the necessary time for soaking after the proper temperature has been reached. The metal is held at a constant temperature to insure an even and uniform heat throughout. The smaller the section of metal, the less time it will take for the heat to soak through. The time recommended for soaking is 1 hour per inch of cross section (thickness).

(3) Cool the metal. After you have brought your piece of metal to temperature and held it at the temperature for the proper length of time, you are ready for the third important step--cooling. In all heat-treating operations, the first two steps are identical. The third step, however, will be to cool the metal in a quenching medium (such as brine) in a furnace. The results desired will determine the method. The time element then may vary from a few moments to 36 hours.

You may be requested to heat-treat any metal or alloy, but the greater part of your work will probably be involved with the treatment of low-, medium-, and high-carbon steels. These steels are basically alloys of iron and carbon plus a minimum amount of other elements.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. List the three steps in the heat-treating process of metal.

a. ______________________________
b. ______________________________
c. ______________________________

2. The purpose of controlling the time, temperature, and manner of heating and cooling is

a. to make the metal harder.
b. to prevent certain elements in the metal from becoming oxidized.
c. to induce malleability into the metal.
d. to prevent burning of the metal.

Work Unit 1-12. CRITICAL POINTS

IDENTIFY THE CRITICAL POINT IN METAL.

Webster says that the word "critical" indicates a crisis or turning point. Throughout the heat-treatment of steel, as well as of other metals and alloys, you will be face to face with critical points and critical ranges.

a. Critical point. In metal, this is the point at which the most radical changes occur inside the metal. These changes are a result of heating. Each type of metal has its own critical point. You will need a lot of experience as a heat-treater before you are able to determine visually when a piece of metal reaches its critical point. You can be sure that some metallurgical laboratory has determined the critical point for any metal that you will work on, and you can get the information from a chart or handbook.

b. Critical range. This is a temperature range of from 50° to 100°F above the critical point. Temperatures required for all of the heat-treating processes fall within this range. The critical range like the critical points for all metals, has been determined in a laboratory and made available for your use in charts and handbooks. You won't be able to heat-treat any odd piece of metal that you pick up around the shop until you can identify it. In order to heat-treat a metal, you must know its composition; then you can determine its critical range from the necessary charts. Knowing its composition and its critical range, you then get the desired property by the proper cooling or quenching method. It may be necessary to treat some tools or machinery parts several times before they are finally completed. For example, you must first soften (anneal) a chisel that has been in service and has been returned to the metal shop for reforging and heat-treating. After forging and rough-grinding the chisel, you will then have to harden it and finally draw it to the proper temper.

c. Color change. Although it is well to know what goes on inside a piece of steel while it is undergoing heat-treatment, you will be more concerned with the changes that you can see. Color change is one of the most apparent changes. As heat is applied uniformly to a bright piece of steel, no color change is apparent until a temperature of the 400°F is reached. At that point a faint straw color appears on the surface. As you continue to apply heat, you will notice various surface color changes. These continue as the heat increases and indicate the degree of toughness and hardness reached in the metal. Here is an experiment that will make you a bit more familiar with the color changes that occur as steel heats. Cut a piece of cold-rolled bar stock 2 by 1 by 3/16 inches. If the piece is not available, brighten a piece of strap iron of approximately the same dimensions on an emery wheel. Be certain that the surface is bright and clean. Now, heat a fire brick in your forge for about 5 minutes. Place your test piece, bright side up, on the brick. Watch it carefully. As the heat radiates from the brick to the metal, the color of the metal will change--first a pale straw, and then on up to and through a light blue. As the metal absorbs more heat, the light blue fades out and no color is visible. As more heat is applied, your test piece will continue to change color. If you are in a shop that is not equipped with a heat-treating furnace with controllers, color will be the only method you will have to determine the temperature of the metal you are treating. Practice will make you good at estimating temperatures. Color is a rough estimate at best, but you will have plenty of chances to use this knowledge and experience in times of emergency. Another visual change which you will observe when the piece reaches a temperature near 1,600°F is scaling. Scale is identical to rust. You have seen scrap iron that has been exposed to the weather for long periods of time, and you have noticed its burned, crumbling appearance. This is an example of oxidation. Scaling is the same thing--the difference is that it occurs faster than ordinary rusting. At high temperatures, the rusting or oxidizing process is greatly accelerated.

d. Internal change. While the surface appearance changes, internal changes are also taking place. If you could see your piece of soft 0.43% carbon steel under a microscope, which enlarges the view of the section on a thousand times, it would look like the view shown in figure 1-6. Now, if that same piece of steel had been heat-treated--and you could get a look at it through the microscope, you would observe considerable change in the grain structure (fig 1-7). Another characteristic of the internal change in metal is grain growth. If you could observe a piece of 0.83% carbon steel during heating, you would observe that the grain size is smallest at about 1,300°F or just as it reaches its critical point. The higher the steel is heated above this temperature, the more the grain will grow in size. In all your work as a practical heat-treater, your greatest concern will be the critical point of the metal or alloy you are treating. You must know the critical point and the alloying ingredients before you start any heat-treating operation. Additional information covering heat-treating for most metals is given in figure 1-8. If you have special steels or alloys to treat, a letter to the manufacturer will bring you all the information that you need.

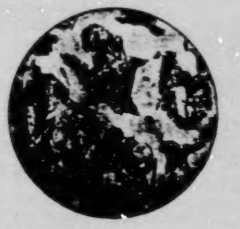

Fig 1-6. Microscopic view of soft (unhardened) 0.43% carbon steel magnified 1,000 times.

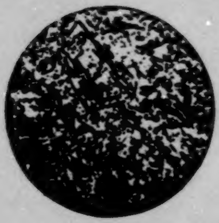

Fig 1-7. Microscopic view of hardened 0.43% carbon steel not tempered.

Metal	Annealing temp	Cooling preheat	Hardening temp	Quenching medium
Carbon steel	50° – 100° F above critical temp	Slow.	50°-100° F above critical temp	Water or oil
Aluminum.	750° F.	Air	Cold work	. . . .
Copper.	932° F.	Rapid	Cold work	Water
Monel	1,400° F.	Rapid	Cold work	Water
Brass	600° – 1,200° F. . . .	Slow.	. . . .	. . . .
Bronze	1,400° F.	Air	. . . .	. . . .
Stellite (Cr-Co-W) . .	2,100°-2,150° F. . . .	Rapid	. . . .	. . . .
Copper Nickel	1,400°-1,450° F. . . .	Rapid	. . . .	. . . .
Stainless steels: . . .				
Cr. 18% Ni. 8% . . .	2,000°-2,300° F. . . .	Rapid	. . . .	. . . .
Cr. 25% Ni. 20% . .	2,000°-2,100° F. . . .	Air	. . . .	. . . .
Cr 8.5% Ni. 22% . .	1,650°-1,750° F. . . .	Slow.	. . . .	. . . .
Cast irons.	50°-100° above critical temp	Slow.	. . . .	. . . .
High-speed steel . . .	1,600°-1,650° F. . . .	Slow to 1,000° 1,450° to 1,600° F	2,250°-2,350° . . .	Oil

Fig 1-8. Primary heat-treating hints.

EXERCISE: Answer the following questions and check your responses with those listed at the end of this study unit.

1. The most radical changes occur inside the metal at the

   a. critical point.
   b. critical range.
   c. internal change.
   d. 1,100° point.

2. The critical range is the temperature range of _________ to _________ degrees above the critical point.

   a. 20, 50
   b. 50, 75
   c. 50, 100
   d. 50, 150

3. Color changes become apparent in metal at a temperature of about

   a. 200°.
   b. 300°.
   c. 400°.
   d. 500°.

4. When heat-treating metal, three changes take place; appearance, grain structure, and

Work Unit 1-13. FORMS OF HEAT-TREATMENT

MATCH THE FIVE MOST COMMON FORMS OF HEAT-TREATMENT WITH THEIR CORRECT DEFINITIONS.

The most common forms of heat-treating ferrous metals are annealing, normalizing, hardening, tempering, and casehardening.

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a. Annealing is used to reduce stresses, induce softness, change ductility, or improve grain structure. The greatest softness you can get in metal results from heating it to a point above the critical temperature, holding it at this temperature until the grain structure has been refined, and then cooling it slowly. The most important step in annealing is to raise the temperature of the metal to the critical point, as this will remove any hardness that may exist. Any strains that may have been set by previous heat-treatment will be eliminated when you have heated the metal to its critical point and restored it to its lowest hardness by slow cooling. Steel is usually annealed to increase its ductility, to refine the crystalline structure, and to remove stresses. Ductility is increased by decreasing hardness and brittleness. In other words, when steel is made softer, it is more workable. You can also alter other physical properties of a piece of steel, such as its magnetism or electric conductivity, by annealing. Refining the crystalline structure of steel simply means changing the internal structure by a process of heating and cooling in such a manner as to remove any stresses or strains that may have been set up by cold-working, forging, welding, or usage. Remember that in annealing, as in all heat-treatment, the temperature of the operation and the rate of cooling depending on the material that you are treating and the purpose for which you are treating. If you have heat-treating equipment, the process of annealing can be done with accuracy. Just check the chart for the critical point of the percent carbon steel you are about to work. Heat it slowly in a furnace to a temperature 50°F above the critical range. Hold (soak) the piece long enough to insure uniform temperature throughout--about 1 hour for each inch of sectional thickness (small tools require only 30 min). Now, assuming that you have heated the part to be annealed to the proper temperature, you will have to decide on a method for cooling. If you want a full anneal, that is, if you want the piece to be as soft as possible, seal the piece in the furnace and allow it to cool down to room temperature in the furnace. This may take 24 to 36 hours. The other method that is commonly used is called packing. To pack, remove the piece from the furnace, being careful to avoid drafts, and bury it in an annealing box (fig 1-9) filled with asbestos or slacked lime, making sure that you leave the piece completely covered 16 to 24 hours, depending on its size. Be sure that the material in your annealing box is perfectly dry. To avoid scaling or decarburizing (burning), you may have to use the box-annealing (pack-annealing) method for some materials. In this method, place the piece to be annealed in a metal box. Completely surround the metal with cast-iron chips and seal the box with fire clay. Place the box in the furnace, heat, hold, and allow it to cool in the sealed furnace as previously described for steel. This method is used when surface finish is important. You may not be fortunate enough to have an annealing furnace. If so, you will have to use a forge or a torch for annealing. The operation is the same, but you will have to exercise a lot more caution in heating holding. On a furnace, when you set the controller it insures the correct temperature. With a forge or torch you are the controller. You must be especially careful to avoid overheating the metal since, this causes increased grain size and there is danger of burning the metal and decarburizing the surface. You must have everything ready to make the transfer from the forge to the annealing box. Make the transfer as quickly as possible, avoiding drafts of air which cause uneven cooling that results in warpage, strains, and fractures.

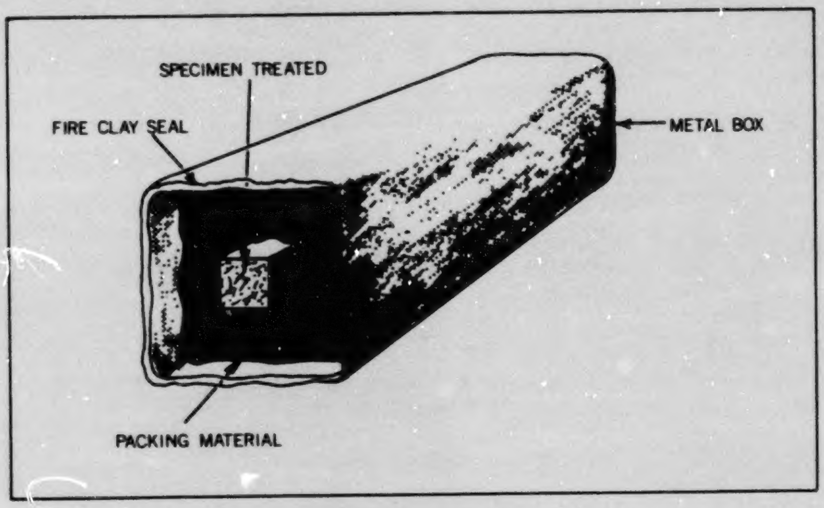


Fig 1-9. Cross-sectional view of annealing box.

Although most often called upon to treat steel, you will occasionally have to treat other material. Other alloys require different annealing operations. An outstanding example of an alloy that requires an entirely different treatment for annealing is duralumin. Duralumin is composed of 94% aluminum, 4% copper, and approximately 1% each of magnesium and manganese. This alloy is annealed by first heating it to 986°F and then cooling it rapidly by quenching in water. For a period of 45 minutes it is in a plastic condition and can be bent, rolled, and worked cold. Beyond this interval, it becomes hard and cannot be further worked without repeating the heat-treatment. This example emphasizes the need for thoroughly knowing the material you are treating. Annealing is a frequent and important process for softening nonferrous alloys and pure metals after they have been hardened by cold work. Annealing restores the ductility, relieves internal stresses, controls grain size and, in the case of copper and aluminum, restores electrical conductivity. Following is a list of the more common metals with instructions for annealing each:

Copper: Heat to 925°F. Quench in water. Temperatures as low as 500°F relieve most stresses and strains.

Aluminum: Heat to 750°F. Cool in open air. Reduces hardness and strength, but increases electrical conductivity.

Zinc: Heat to 400°F. Cool in open, still air.

Brass: Annealing to relieve stress may be accomplished at a temperature as low as 600°F. Fuller anneals may be accomplished with increased temperatures. Larger grain size and loss of strength will result from too-high temperatures. Do not anneal at temperatures exceeding 1,300°F. Brass should be cooled to room temperature slowly. Either wrap the part with asbestos cloth or bury it in slaked lime or other heat-retarding material.

Bronze: Heat to 1,400°F. Cool in open furnace to 500°F or place it in a pan to avoid uneven cooling caused by drafts.

Nickel-copper alloys, including monel: Heat to between 1,400° and 1,450°F. Cool by quenching it in water or oil.

Nickel-molybdenium-iron and nickel-molybdenum-chromium-iron alloys (known commercially as stellite): Heat to 2,100°F. Hold at this temperature a suitable time, depending on thickness, followed by rapid cooling in a quenching medium.

Stainless steel (Cr 18% Ni 8%): For full anneal, heat it to 2,000° - 2,200°F. Cool rapidly for partial anneal, heat to 1,600° - 1,700°F.

Stainless steel (Cr 25% Ni 20%): Heat to 2,000° - 2,100°F. Do not soak. Cool it in still air.

Stainless steel (Cr 8.5% Ni 22%): Heat to 1,650° - 1,750°F. Do not soak. Cool it slowly to room temperature.

Cast iron: Heat slowly to 800° - 1,300°F, depending on composition. Hold at temperature for 30 minutes. Cool slowly in furnace annealing box.

Ask yourself these questions before you begin any annealing.

(1) Which metal or alloy do I have to treat?

(2) What is its critical point?

(3) Am I annealing to relieve stress, to aid machining, or to alter magnetic or electrical properties?

(4) Which upper temperature shall I use?

(5) How long shall I "hold" at the upper temperature?

(6) Which method and rate of cooling shall I use?

When you have answered these questions and have made all preparations, you are ready for the annealing operation.

b. Normalizing. Normalizing involves a slightly different heat-treatment than for annealing, but it may be classed as a form of annealing. It is a process whereby iron-base metals are heated above their critical temperatures to get a better solubility of carbon in the iron, followed by cooling in still air. The process removes all strains due to machining, forging, bending, and welding. You can process normalizing only with a good furnace where the temperatures and atmosphere can be closely regulated and held constant throughout the entire operation. Reducing atmosphere will normalize metal with a very small amount of oxide scale; but an oxidizing atmosphere will leave the metal heavily coated with scale. This outside scale will prevent outside hardness in any other hardening process. The term "decarburization" is used to describe the surface condition of metal when it has had a portion of the carbon content of the surface burned out. Remember that a piece of steel designed for a particular job will have to be machined to certain dimensions. The machining must remove all of the decarburized surface from the piece without reducing it to less than the required dimensions. Always select an oversize piece of metal which will allow for this machining. This extra metal is called an "allowable tolerance." Remember that you can control this burning or decarburization considerably by the use of neutral or slightly carburizing atmospheres in the furnace. If you have an oilfired forge instead of the latest thing in heat-treating furnaces to work with, be sure that you do not have an excessive blast of air going into the firebox. You may have only a multiple-tip torch. If so, you then must exercise great care to avoid decarburization. Some alloys, such as the chromium types, are normalized prior to the regular heat-treatment operation. Normalizing softens steel somewhat, but it does not affect its strength to any great extent. The precautions applicable to annealing also apply to normalizing. These are the steps to be remembered:

(1) Heat the piece to be normalized to a temperature of 50° to 100°F above its critical point.

(2) Hold the piece at this point until the heat has had time to soak through to the center of the section. Avoid prolonged soaking of the metal at high temperatures, as this will cause the grain structure to enlarge.

(3) Remove from the furnace and cool in still air. Avoid drafts; they cause uneven cooling which in turn causes strains in metal.

c. Hardening.

(1) Heat control. Hardening of metals and alloys can be done in several ways. Copper is hardened by rolling or working, but steel requires a different process. To harden steel, you must heat the metal to a little more than its critical temperature, then cool it rapidly by quenching it in oil, water, or brine. The treatment gives the steel a fine grain structure, extreme hardness, greater tensile strength, and less ductility. Steel, after being hardened, is generally too brittle for most practical uses, although this treatment is the first step in the production of high-strength steel. To harden steel successfully, you must:

(a) Control the rate of heating to prevent cracking of thick and irregular sections.

(b) Heat thoroughly to correct hardening temperature. Soak time required depends on the size of section of metal being treated.

(c) Control furnace atmosphere which is required, in certain steels, to prevent scaling and decarburization.

(d) Use suitable quenching media. Quenching medium must have the correct heat capacity, viscosity, and temperature to obtain adequate hardening without cracking.

Most of your work in hardening is employed in carbon tool steels. These steels contain from 0.7% to 1.5% carbon. The treatment of all steels in this class is the same except for the variation in critical point. The critical point in hardening, as in all heat-treating, determines the temperature to which the steel must be heated. Ordinary carbon steels are heated to between 1,350° and 1,500°F. These steels are supplied in the unhardened condition, in various sizes and shapes, such as rods and bars. They can easily be shaped into the desired form by forging or machining. In its unhardened state, tool steel is of little value, but when it is properly hardened and tempered, it takes on properties that enable it to cut other metals. The common cold chisel is a tool that demonstrates the properties of hardness and toughness that can be developed in carbon steel through hardening and tempering treatments. Carbon tool steel is hardened by slow heating to a temperature of 50° to 100°F above the critical temperature and sudden cooling by quenching in water or oil. Remember that the critical points of steel vary with the alloying ingredients. In carbon tool steel, the higher the carbon content of the steel, the lower the critical point.

(2) Quenching. This is a process of which heated metal is rapidly cooled by placing it in water, oil, or some other quenching medium. Any solution used for cooling metal in the heat-treating process is referred to as a quenching medium. A number of liquids may be used for quenching steel. Both the quenching medium and the form of the bath depend largely on the nature of the work to be cooled. It is important that you have enough of the medium to cool the metal without changing the temperature of the bath. This is especially important when you have a number of pieces to quench, one after the other. It is hard to keep steel from warping and cracking during the quenching process since certain parts of the metal cool more rapidly than others. When the change in temperature is not uniform, internal strains which may be sufficient to cause warpage or cracking are set up. Odd or irregularly shaped pieces are more likely to be affected by internal strains than are even sections. Forging and machining may also set up internal strains in steel parts; therefore it is advisable to normalize these articles before attempting to harden them. To reduce the tendency of steel parts to warp, you should pay attention to the following recommendations:

- Dip the article to be quenched into the bath. Never throw it in or allow it to lie on the bottom of the bath. If you let the part lie on the bottom of the bath, it is liable to cool faster on the top than on the bottom, thus causing it to warp or crack.

  - Don't allow the part you quench to remain motionless in the bat[illegible]e heat will cause a coating of vapor to be formed around the part which will prevent it from cooling rapidly. Keep moving it. The stirring allows the bath to convey the heat to the atmosphere.

  - Quench the piece so that all of its parts will be cooled uniformly and with the least possible distortion. Quench these parts as a gear wheel or shaft in a vertical position.

  - Dip or immerse odd-shaped steel parts so that the thickest section will enter the bath first.

(3) Quenching media. Commonly used quenching media are fresh water, salt water (brine), and oil (fig 1-10).

(a) Water. This is often used as a quenching medium. It is not ideal, however, because of the bubbles which form on the surface of the tool or part being quenched, especially in holes or recesses. These bubbles retard the cooling process and cause soft spots which are likely to weaken the steel. If you do not use water, be sure to keep moving the object being quenched to avoid, as much as possible, the formation of gas around the metal part. Keep the water bath at about 70°. Extremely cold water might warp or crack the steel; water above 70° will not produce the required hardness.

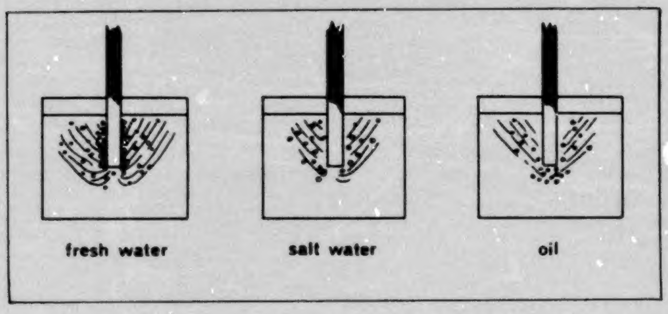


Fig 1-10. Comparison of quenching media.

(b) Salt water (brine). This medium is much better to be used as a quenching bath than fresh water. When the brine is quiet (not in motion), it is referred to as still brine. The most satisfactory brine bath is made by dissolving ordinary salt in the water until a 5% to 10% solution is obtained. The salt in the water causes the water to "take hold" and wet the heated steel tool or the part evenly. This wetting causes the quenching to proceed uniformly. Brine also "throws scale" better and usually gives you a cleaner tool or part.

(c) Oil. Oil is slower acting than water, and it is, therefore, better for quenching heated steel, because its slower action greatly reduces the tendency of the steel to warp or crack when quenched. Unfortunately though, parts made of high-carbon steel will not develop their greatest possible hardness when quenched in oil unless they are quite thin. It is best to use, however, since it will produce the required hardness. Oil quenches should have a high flashpoint, low viscosity, and a constant composition. They should be kept at temperatures of 140° to 160°F.

(4) Quenching bath. Agitators may be used to keep the quenching media circulating, or they may be designed for continuous circulation by means of a circulating pump. You will have to keep your bath at the proper temperature by the best means at your disposal. For example, if your quenching bath is too cool, you can heat it with hot pieces of scrap metal until the proper temperature is reached. Here are a few points that you should keep in mind:

* The quenching rate of the medium drops as its temperature rises.

* Near the boiling point, the quenching medium has less than 10% of the quenching rate, or the ability to cool, than it has at 68°F.

* More heat will be driven away if the piece is kept moving about in the bath. This dispel of heat is called heat dissipation.

Some iron alloys are classed as water-hardening, others as oil-hardening. Some high-speed steels are called air-hardening. Again, as in any phase of heat-treating, you must know just what kind of metal or alloy you are working with. If you make the mistake of quenching an oil-hardening tool in water, you are liable to crack the tool. Water's faster rate of cooling is too harsh and abrupt for alloys classed as oil-hardening metals. Plain carbon steels have a high rate of cooling, therefore cooling by quenching can't be too fast for them. Additions of alloying elements to steels lower their critical cooling rate, and thereby require the use of a quenching medium that has a slower cooling rate. If there is any doubt in your mind about the method of heating and cooling required for a particular piece of metal, your best solution is to obtain the stock number for that particular piece of metal. From the stock number, you can find the Navy specifications for that stock. The specifications will give you the information that you need about the alloying elements and tensile strength of the metal. From this information you can judge the critical temperatures and the best method for heating and cooling by comparing the metal in question with another metal for which you know the proper treatment. Hardness, distortion, and internal stresses are all results of the cooling rate. Oils, therefore, produce less distortion and fewer stresses in steel than other quenching media. Mineral oils are generally used for quenching, as they are less expensive than other oils. Also they are of a more stable nature than other oils; that is, they are not subject to decomposition.

d. Tempering.

(1) Drawing. This is a process which is generally applied to steel to relieve the strains that are brought about during the hardening process. Drawing is done by heating the hardened steel to a temperature below the critical range, holding this temperature for sufficient time for it to completely penetrate the piece, and then cooling in water, oil, or air. In this process, as in the other heat-treating processes, as you gain one property you lose others. For example, in tempering, you improve the ductility and toughness, but at the same time, you loose some of the tensile strength, yield strength, and hardness. The temperature to which you will reheat hardened steel is determined by the degree of hardness and toughness desired. The tempering range is from 400°F to a point just below the critical point. The upper temperature is usually about 1,000°F. Tools designed to have cutting edges are not above 600° to 700°F. A file is a cutting tool which may be very hard and brittle. Since it receives little shock or pressure, brittleness

is no disadvantage. A chisel, on the other hand, is subjected to tremendous shock, therefore must be tough, not brittle, and its head must be soft to receive the blows. By trial you will soon learn the degree of head to which a tool must be tempered. You can be guided by figure 1-11, which gives the tempering heats for various tools in degrees Fahrenheit.

Degrees Fahrenheit	Tool
400°	Hammer faces, machine cutting tools
460°	Taps and dies
480°	Punches, reamers, dies, knives
500°	Twist drills
520°	Driftpins, punches
540°	Cold chisels
550°	Screwdrivers, springs

Fig 1-11. Temperatures for tempering various tools.

(a) Again there is the problem of controlling the heat. In drawing, it is the tempering or reheat temperature. If you have a tempering furnace you only have to set the controlling devices. If you don't, you must improvise and complete the hardening and tempering treatment as best you can. Several methods of reheating are possible in any sort of shop setup. You must use what you have. One method is the use of firebrick. You used it to run out the heat color earlier in this chapter. The heat colors will be your only guide to temperature when you use reheat methods of this type. Another good way of reheating for tempering is shown in figure 1-12.

(b) You have a metal box filled with sand. The source of heat is an oxyacetylene or other type of torch. The hardened tool, in this case a center punch, must have a bright clean surface or the heat colors won't indicate the true temperature. First, rub the tapered end of the punch briskly with emery cloth until it is bright and clean. Then insert it in the hot sand, head down. The heat of the sand is absorbed by the head-end of the tool and travels up to the point by conduction. As more and more heat is absorbed by the tool, the point gets hotter. You will notice the color change on the brightly polished end. When the desired temperature is reached, the color indicating the temperature appears on the point of the tool. This temperature should be 400° to 600°F or as indicated by a deep straw color. Now, with a pair of pickup tongs, remove the punch and quench it to prevent more than the desired amount of heat from reaching the point. Because of the varying amounts of heat that have been attained in the tool from head to point, a varying degree of hardness will be present in the tool; the point will be hard and capable of penetrating metals, the shank will be tough, and the head will be soft enough to withstand the continued blows of a hammer.

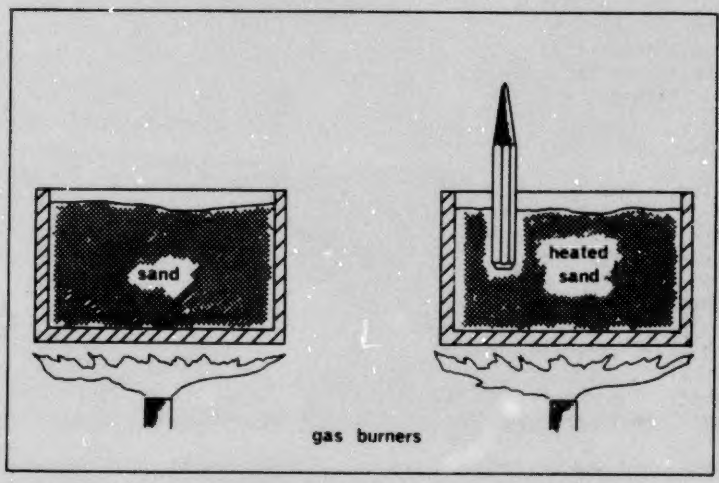


Fig 1-12. A method of reheating for tempering chisels, punches, etc.

(c) Another common method employs chisels. Bring the temperature of 2 1/2 or 3 inches of the cutting edge of the tool up to the hardening point. Quench the tool by plunging about 1 1/2 or 2 inches of the heated end into the quenching medium and jiggling it rapidly in an up-and-down and forward-and-backward motion being sure to keep the point immersed 1/2 inch in the quenching tank at all times (fig 1-13).

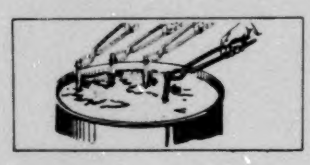


Fig 1-13. Quenching a chisel.

(d) When the metal is cooled to a black heat (900° to 950°F), remove the tool from the quench tank, quickly polish the tapered end with an emery board, and watch the temper color "run out" until the desired color appears (usually a dark blue). Quench the entire tool to stop further heat of the cutting edge.

(e) It is well to remember that every chisel you see is not a water-hardened chisel. Many are manufactured from special alloys and are oil-hardened. Most chisels of this type have directions for treating stamped on the shank as follows: 1,350 W 400 or 1,600 O. The first means to heat to 1,350°F, quench in water and temper at 400°F. The second means to heat to 1,600°F and quench in oil. It isn't necessary to temper such a tool, as it is a special alloy. Other alloy chisels will have different directions stamped on the shank, which is another reason why you should pay attention to the rule "Know the metal you are working!" Generally it is safe to assume that an unmarked chisel is a carbon steel water-hardened tool, but give it a spark test to identify it.

(f) Equipment for quenching baths consists of tanks, circulating pumps, and coolers. Tanks must be large enough to allow the liquids to remain at about room temperature. If you do a lot of quenching, you will probably have circulating pumps and coolers to keep fairly constant temperatures.

(2) Toughening. The only difference between this operation and tempering is that higher drawing (reheat) temperatures are used (700° to 1,300°F) in toughening. This operation is used when the property of hardness is unimportant and shock resistance and toughness are desired.

e. Case Hardening

(1) This process consists of causing the surface of a piece of steel to absorb carbon. A thin shell having the properties of tool steel is formed upon the surface of the piece. The case or shell can be hardened by heating and quenching as though it were tool steel. Only the case, which has a high-carbon content, becomes hard, while the core remains soft, tough, and ductile. The case can be varied in depth from a few thousandths of an inch to an eighth of an inch or more, depending upon the process used.

(2) Several processes are available for adding carbon to the surface of steel. In the pack hardening process, the parts are packed in charred bone or charred leather in a closed iron container and heated for a considerable time in a forge or furnace. The longer the time, the deeper the case. In the cyanide process, the parts are heated in a bath of molten potassium cyanide. Since cyanide is one of the most dangerous poisons known, it should never be attempted except under expert supervision. The oxyacetylene flame, adjusted to give a carburizing mixture, can also be used to increase the carbon content in a thin layer on the steel surface.

(3) The nitrogen case hardening process, which is known as nitriding, consists in subjecting the machined and generally heat-treated materials to the action of a nitrogenous substance; commonly ammonia gas, under certain conditions thereby, surface hardness is imparted to the material without any further treatment.

EXERCISE: Match the forms of heat-treating one through five, in column 1 with their correct definitions, "a" through "e", in column 2.

Column 1

1. Annealing
2. Normalizing
3. Hardening
4. Tempering
5. Casehardening

Column 2

a. Gives steel a fine grain structure, extreme hardness, greater tensile strength, and less ductility.
b. Iron base metal is heated above its critical range and cooled in still air.
c. Is used to reduce stress, induce softness, change ductility, or improve grain structure.
d. Causes the surface of a piece of steel to absorb carbon.
e. Heats steel to a temperature below critical range, holding until heat penetrates completely, and cooling in water, oil, or air.

Work Unit 1-14. HEAT-TREATING EQUIPMENT

IDENTIFY THE THREE TYPES OF HEAT-TREATING FURNACES.

Equipment needed for heat-treating consists of a suitable means for bringing the metal to the required temperature, a temperature-measuring device, and a quenching medium. Heat may be supplied by a forge or welding torch; however, you will do the job a lot easier and better if you have a heat-treating furnace to work with.

Furnaces. The equipment that you have will determine the manner in which you perform the various heat-treating operations. Your method of temperature control will greatly influence the results you obtain. The more rigidly you can maintain control, the more uniform your work will be. You probably won't have the most modern equipment to work with and may have to depend on your eye to judge heat. Supprisingly good work is done by experienced heat-treaters using the "eye of judgement." With sufficient experience, you too can become adept at this method of determining temperature.

a. Oil-fired and gas-fired furnaces. These are constructed so that he firebox is enclosed in a casing of steel plates electrically welded together and mounted on a steel frame. The lining of the furnace is made of firebrick, installed by a couple inches of magnesia. The magnesia lets the firebrick expand without danger of damaging the steel casing. The heating chamber is made of semirefactory brick, which allows for quick heating. The hearth plates are usually made of heat-resisting alloy with suitable flanges for holding the work in place. Furnaces are made to keep the same temperature throughout all parts of the heating chamber.

b. Electrically heated furnace. This has the advantage of being quiet, clean, and constant in operation. The heating element of an electric furnace will be either of the metal or carbon-resistor type. Metal resistors are used where temperatures don't go over 2,000°F. Carbon resistors are used for higher temperatures. Most shops have two furnaces. One is for low-temperature operation, where most heat-treatment can be done; and the other, although smaller in size, is a higher temperature furnace. It is capable of the high temperatures necessary for some of the high-speed and special alloy steels.

c. Bath furnace. This is often used for small parts that have been machine-finished and have to be heat-treated. Parts that are too large to be treated in a closed furnace may be treated in a bath furnace. A bath furnace is simply a melting pot filled with molten salt, lead, or oil, and surrounded by firebrick. The bath is kept at the required temperatures by means of electrical resistors. Figure 1-14 is a schematic drawing of a bath furnace.

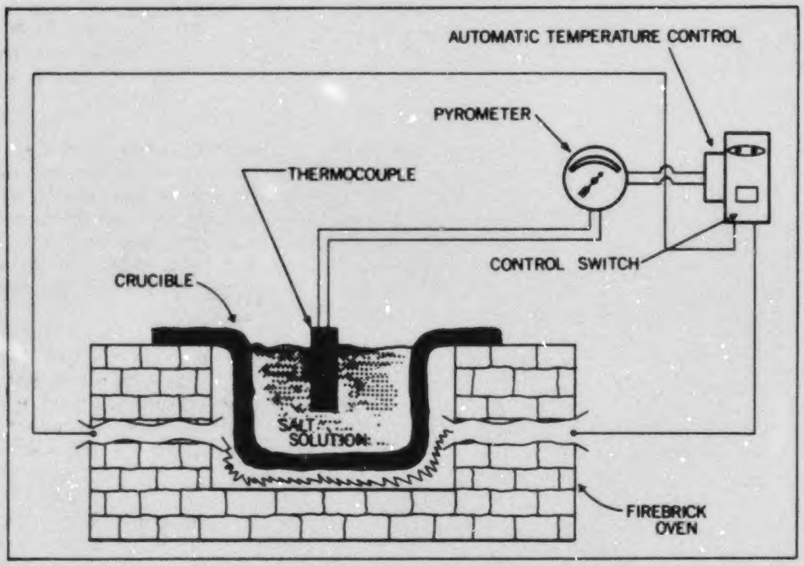


Fig 1-14. Salt bath furnace.

(1) Lead and oil-bath furnaces are principally for tempering, while salts may be procured for any temperature range. However, it is well to remember that low-temperature tempering salts are not capable of withstanding temperatures needed for high-alloy steel hardening. Parts heated in the salt bath are free of scaling, but you should be very careful to remove all traces of the salt after the treatment.

(2) Generally, shops equipped with salt bath furnaces will have three furnaces in addition to the lower heat temperature baths that may be available. The temperature ranges for the three baths will be as follows: 1,000° to 1,550°F; 1,450° to 1,950°F; and 1,800° to 2,350°F. Considerably less time is required for heating with the bath furnaces than is required when heating with air furnaces. When the salt bath furnace is used, the entire piece is immersed in the solution. This excludes air from the piece so that no scaling can occur, and the piece will be bright and clean.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. All the ones listed bellow are types of heat-treating furnaces, EXCEPT ________ furnace.

   a. oil and gas fired
   b. coal fired
   c. electrically heated
   d. bath

2. The best way of heat-treating metal is with a

   a. forge.
   b. furnace.
   c. welding torch.
   d. cutting torch.

Work Unit 1-15. THE PYROMETER

IDENTIFY THE DEVICE USED TO MEASURE THE TEMPERATURE IN THE HEAT-TREATING PROCESS.

Measuring devices. The device for measuring and controlling temperature are very important. Temperature variation of a few degrees may seriously affect the physical properties of the metal you are working. In order to get good results, you should use a thermoelectric instrument known as a pyrometer to measure the temperature of the metal being heated.

a. A pyrometer (fig 1-15) consists of a thermocouple, extension leads, and a meter. It works as follows: If you twist or weld two wires of different metals together and heat them, you will generate electromotive force or voltage. You can measure this voltage by connecting the cold ends of the wire to a galvanometer that is sensitive enough to read thousandths of a volt. At this point mathematics is useful. The voltage that you have measured is proportional to the difference in temperature between the hot and cold ends. In other words, the hotter the wires get, the more voltage is generated. Since the pyrometer has been marked off in degrees instead of electrical units, it measures heat.

b. The thermocouple used in pyrometers for measuring temperatures up to 2,000°F is generally of lower priced iron, copper, nickel, or chromium. The more expensive ones of platinum and rare metal combinations may be used to measure a temperature up to 3,000°F. The thermocouple is the portion of the pyrometer that is inserted in the heat-treating oven to measure temperature. In bath furnaces, the thermocouple is inserted in the molten solution itself.

c. Alloy extension leads are made of the same material as the thermocouple. In effect, you might consider the thermocouple as extending from the furnace to the meter. By the use of leads, you can put the meter far enough away from the furnace so that the cold ends won't be affected by the sudden changes in temperature. These leads are carried in parallel and are covered with heat-resisting insulation.

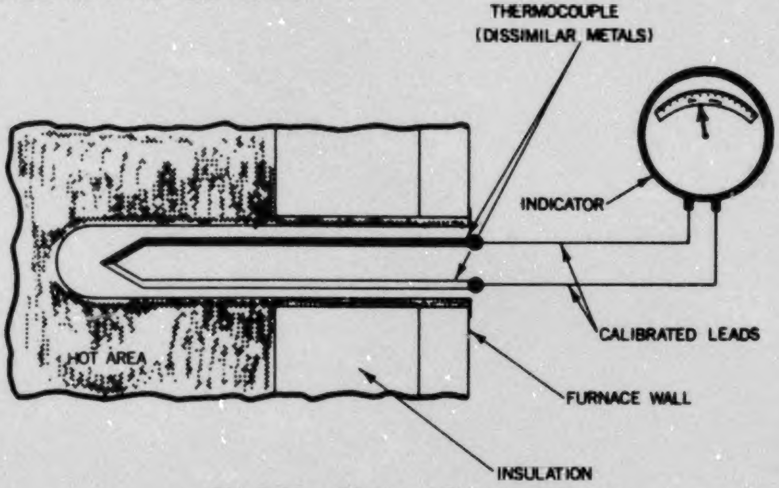


Fig 1-15. Diagram of a pyrometer.

d. The meter in the pyrometer does not really indicate the temperature of the hot end of the thermocouple, but registers the difference in temperature between the hot and cold ends. This means that the temperature of the cold end has to be known and held constant. This is taken care of automatically, either by a thermostat which operates a control spring to make the correction automatically, or by zero adjuster which you must operate by hand.

e. Pyrometers may be of either the indicating or the recording type. The indicating type must be read while the heating is being done. The recording type makes a permanent record of the temperature range throughout the heating operation. Modern furnaces have pyrometers called "controller potentiometer pyrometers," which you can set at any desired temperature to regulate the heating. Many gas- and oil-fired furnaces are equipped with controllers which regulate and maintain any desired heat within range of the furnace design.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. An instrument used to measure the temperature of the metal being heated is a

   a. pyrometer.
   b. thermometer.
   c. temperature gage.
   d. thermostat.

2. How many types of pyrometers are there?

   a. 1
   b. 2
   c. 3
   d. 5

Work Unit 1-16. ATMOSPHERE CONTROL UNIT

IDENTIFY THE MAIN PURPOSE OF AN ATMOSPHERE CONTROL UNIT.

Atmosphere control. Proper atmosphere control is essential to good heat-treating. Some heat-treating furnaces have an atmosphere control unit attached. A cross-sectional view of the controlled atmosphere hardening furnace is shown in figure 1-16. The construction of all air furnaces is similar, but you can find the exact details of the construction of your furnace in the manufacturer's instruction manual along with instructions for operating the furnace.

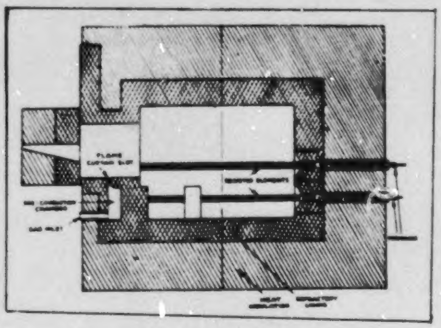


Fig 1-16. Sectional view of controlled atmosphere hardening furnace.

The main purpose of atmosphere control is to keep the metal from oxidizing. Either a neutral or slightly reducing atmosphere will serve this purpose. A neutral atmosphere is one which has no excess of either fuel or air. A reducing atmosphere has an excess of combustible gases. In the oxidizing atmosphere which contains an excess of air, that you must guard against. After a little experience, you will be able to judge the atmosphere by character of the flame. A long, lazy flame indicates excess fuel or a reducing atmosphere, while a blue flame at the burner, short and "sharp," indicates an excess of air or an oxidizing atmosphere. Atmosphere can also be judged by observing the smoke, flame, and burning of small 3/4-inch cubes of wood. The character of the burning cube changes from that of charring in a reducing atmosphere to that of rapid burning, as the oxygen or ratio of air to fuel is increased. To change the atmosphere from oxidizing to neutral or to slightly reduce it, you increase the ratio of fuel to air. On oil- or gas-burning furnaces, you adjust the fuel and air valves which control the heat of the furnace. On the electric furnace, you change the atmosphere by adjusting the fuel and air valves on the atmosphere control unit attached to the furnace. Each steel has its correct atmosphere.

(a) High-speed steel--a reducing atmosphere (excess of fuel).

(b) Alloy steel hardening from 1,650° to 1,800°F--a neutral atmosphere. A desirable atmosphere for high-speed and alloy steels may be obtained by pumping an inert gas, such as helium, into the furnnace chamber. Helium permits no oxidation or similar chemical action at any temperature.

(c) Carbon and low-alloy steels hardening from 1,400° to 1,650°F--a neutral atmosphere, slightly on the oxidizing side.

EXERCISE: Answer the following questions and check your responses with those listed at the end of this study unit.

1. The main purpose of an atmosphere control unit is to keep the metal from

   a. oxidizing.
   b. melting.
   c. reaching critical point.
   d. burning.

2. Identify the most essential element in good heat-treating of metal.

   a. Fuel regulation
   b. Atmosphere control
   c. Correct amount of solution in bath furnace
   d. Thickness of the fire bricks

3. Atmosphere can be judged by observing flame, burning of small 3/4 inch cubes of wood, and by ____________________.

   a. burning a charcoal briquet
   b. observing color changes in the metal
   c. the smoke
   d. the amount of fuel being inducted into the furnace

SUMMARY REVIEW

At various times during your career, you will have the occasion to draw from supply and frequently use materials described in this chapter. Although a given metal or alloy is available for your use in a variety of forms (sheets, bars, pipes, and structural shapes), it has certain characteristics and properties which make it more suitable for some applications than for others. An important part of your job is to know the properties and characteristics of the materials with which you work. Many of the identification tests discussed in this chapter will be in daily use in some shops. In other shops, your opportunities for gaining experience with these methods are limited. In either case, keep your eyes and ears open. Familiarize yourself with the materials used by your shop. When you have the opportunity, use the tests along with the characteristics, as described in this chapter, for metal identification on known samples; then, when you need to identify an unknown piece of metal, you will know and recognize the characteristics peculiar to it. Only practice and experience can make you an expert with metal identification.

Answers to Study Unit #1 Exercises

Work Unit 1-1.

1. c.
2. To control and direct the heat on the edges of the metals to be welded and add a suitable filler material to the pool of molten metal.
3. a.
4. a. MIG (Metal Inert Gas)
   b. TIG (Tungsten Inert Gas)

Work Unit 1-2.

1. Physical Properties - Are metal properties determined by chemical compositions which cannot be changed by heat-treatment.

2. Mechanical Properties - are the characteristics of a metal that enable it to resist deformation by external forces.

Work Unit 1-3.

1. a.
2. c.
3. d.
4. b.
5. c.
6. b.
7. d.
8. d.
9. d.
10. (1) Chromium
    (2) Manganese
    (3) Molybdenum
    (4) Nickel
    (5) Tungsten
    (6) Titanum an Columbiam
    (7) Vanadium

Work Unit 1-4.

1. d.
2. c.
3. a.
4. e.
5. b.

Work Unit 1-5.

1. a.
2. b.
3. c.
4. a. The class to which the steel belongs.
   b. The percentage of the predominant alloying agent
   c. The average carbon content in percent.

Work Unit 1-6.

1. The ability to identify metal by the color and texture of the surface appearance.

Work Unit 1-7.

1. This test is made by removing a small amount of material from the sample of metal with a sharp, cold chisel.

Work Unit 1-8.

1. This test is made by holding a piece of metal lightly against a grinding wheel and observing the sparks given off.

Work Unit 1-9.

1. This test is made by studying the behavior of the metal under the oxyacetylene torch.

Work Unit 1-10.

1. The process by which certain desired properties are developed.

Work Unit 1-11.

1. a. Get the metal hot
   b. Hold the heat
   c. Cool the metal
2. b.

Work Unit 1-12.

1. a.
2. c.
3. c.
4. Grain Growth

Work Unit 1-13.

1. c.
2. b.
3. a.
4. e.
5. d.

Work Unit 1-14.

1. b.
2. b.

Work Unit 1-15.

1. a.
2. b.

Work Unit 1-16.

1. a.
2. c.
3. a.

STUDY UNIT 2

ARC WELDING PROCESS

STUDY UNIT OBJECTIVE: UPON SUCCESSFUL COMPLETION OF THIS STUDY UNIT YOU WILL IDENTIFY THE BASIC ELEMENTS OF ELECTRICITY IN ARC WELDING. IN ADDITION, YOU WILL IDENTIFY THE CONSTRUCTION AND TYPES OF WELDS, ARC WELDING MACHINE ACCESSORIES, ARC WELDING PROCEDURES, AND WELDING SAFETY PRACTICES.

Work Unit 2-1. ELECTRICITY IN ARC WELDING

IDENTIFY THE RESULTS OF WELDING WITH "TOO LONG AN ARC."

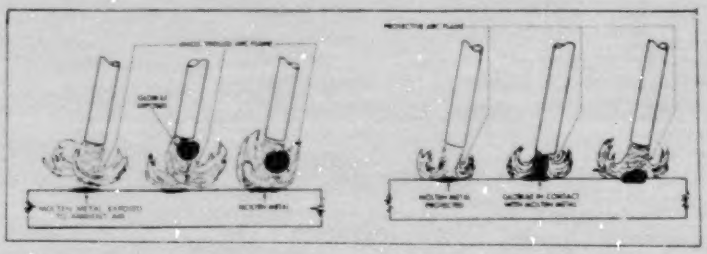
IDENTIFY THE CORRECT PLACEMENT OF THE ELECTRODE AND GROUND CONNECTION FOR STRAIGHT OR REVERSE POLARITY.

IDENTIFY THE TERM "ARC BLOW" AND PROCEDURES FOR CORRECTING IT.

ELECTRICITY IN ARC WELDING

a. Fundamentals. So that you can understand the process of electric-arc welding, a few basic facts about electricity should be known. One of the first facts is that a current of electricity will not flow unless there is a complete conducting path and electrical circuit. An electric current flows along a conductor just as water flows through a pipe. To move this water, there must be a means such as a pump or a difference in the water levels. In the same manner, electric current will flow along a wire when there is a difference of "pressure" created by a battery or generator. The unit of force or pressure that tends to move electricity is the volt. You measure the rate at which water flows through the pipe as gallons or cubic feet per second. In much the same way, the rate at which electricity flows becomes a certain quantity flowing per second past a certain point. This is called an ampere. The amount of current flowing in the circuit depends on the pressure (voltage) and the resistance (ohms) to the flow of current (amperes).

b. Arc-welding principles. The proper length of the arc in arc welding (fig 2-1) is important for good welds. With the proper arc length, the heat is concentrated on the work. If the arc is too long, the heat will escape to the surrounding areas and penetration will be insufficient. A short arc is more stable than a long arc, and the vapors from the burning electrode (rod) surround the arc pool and prevent air from reaching these hot areas. Proper arc length cannot be accurately judged by eyesight but can be recognized by sound. A sharp crackling sound should be heard while the electrode is moved down to and along the surface of the work. When a circuit carrying a current breaks, the current continues to flow across the gap between the terminals until the space becomes too long. For bridging this gap, superheated gases from the heated atmosphere and particles of metal from the terminals carry the current. This action causes an intense white light called the electric arc. Since the resistance in this arc is high, a large amount of electrical energy converts heat in the arc. The proper arc length causes the metal exposed to it to melt instantly. It is the heat produced this way that is available for electric-arc welding. The dc arc-welding machine used for electric-arc welding has a generator driven by some motive power (gas or diesel engines). The voltage of the generator will usually range from 15 to 45 volts across the arc, although the setting may vary because of changes in arc length. Current output will vary from 20 to 800 amperes, depending on the type of unit. In most welders, the generator is a variable-voltage type, arranged so that the voltage automatically adjusts to the demand of the arc. You may manually adjust amperage of the welding current. Usually you may set it at the proper range by means of a selector switch or by a bank of plug receptacles. Using either method, you obtain the desired amperage by connecting the field coils of the generator at different points to either increase or decrease its strength. When you can manually adjust the voltage and amperage of the welder, the machine is a dual-control type. The welding circuit (fig 2-2) consistds of a source of welding current and an electrode lead attached on one end to the power source and to the work on the other. In any electric circuit, current flows only when the circuit is closed. Welding current flows through the welding circuit only when an arc is established between the electrode and the work. When a dc welding circuit is closed, the current flows from the positive terminal through the circuit to the negative terminal of the generator. The terminal to which the electrode cable is connected defines the polarity, which is important because it determines whether the greater portion of the welding heat developed is concentrated on the electrode side or the work side of the arc. Studies have shown that about two-thirds of the heat of the arc is developed at the positive pole. Thus, in straight polarity (electrode negative), the greater portion of the heat developed is concentrated on the work side of the arc. In reverse polarity (electrode positive), the greater portion of the heat is concentrated on the electrode side of the arc. Early in the history of welding, when bare steel electrodes were used, it was necessary to connect the electrode to the negative terminal and the work to the positive terminal. This procedure became known as straight polarity. However, when heavy-coated electrodes were introduced, it was necessary to reverse these connections, hence the name reverse polarity. Again, in brief, straight polarity means the electrode is negative; reverse polarity means the electrode is positive. If the operation of covered electrodes with reverse polarity is compared with the operation of the same electrodes with straight polarity, you will observe that reverse polarity gives slower electrode burn-off rates. At the same time, penetration is deeper and more certain and the weld metal is more fluid and slower to freeze.


PROTECTIVE ARC FLAME
MOLTEN METAL EXPOSED TO AMBIENT AIR
MOLTEN METAL
MOLTEN METAL PROTECTED
GLOBULE IN CONTACT WITH MOLTEN METAL

A. Arc length too long.

B. Short arc, more stable.

Fig 2-1. Characteristics of arc length.

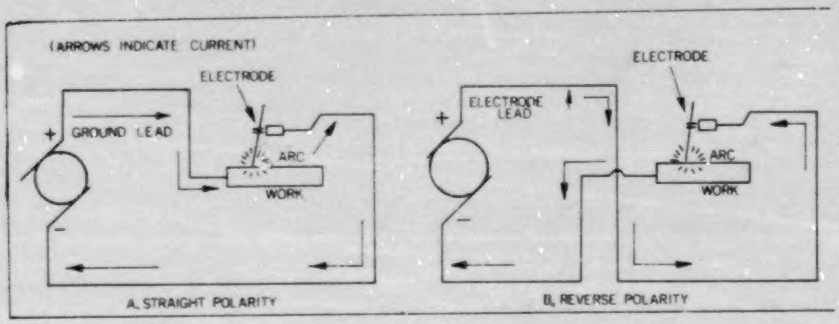

(ARROWS INDICATE CURRENT)
+
GROUND LEAD
ELECTRODE
ARC
WORK
−
A. STRAIGHT POLARITY
+
ELECTRODE LEAD
ELECTRODE
ARC
WORK
−
B. REVERSE POLARITY

Fig 2-2. Polarity of welding currents.

c. Depositing filler metals. Filler metal transferred from the electrode tip to the base metal is probably the result of a number of forces. Some of these forces have little effect on the transfer of the metal. Others are theory. The forces commonly thought to be involved are gravity, surface tension, gas expansion, electromagnetic forces, and vaporization and condensation. Some of these forces play a bigger part in the transfer than others. A brief discussion of each force follows.

(1) Vaporization. An intense heat is developed by the arc, but this heat energy is sufficient to vaporize only a small portion of the metal at the electrode tip. Some of this vaporized metal passes through the arc and then condenses when it contacts the molten pool on the base metal which is much cooler. Another portion of the vaporized filler metal escapes the surrounding air and appears as spatter. Since only a small portion of the filler metal is vaporized and since the bulk of the filler metal from the electrode is actually transferred to the weld, it follows that additional forces are at work.

(2) Gravity. This may account for some metal transfer in the flat position. However, since the rate of metal transfer is as great in the vertical and overhead positions, gravity does not appear to be an important factor. In fact, metal transfer in arc welding seems to defy the force of gravity. Actually, gravity may become a problem in the overhead position if the molten pool of metal becomes so large that surface tension cannot contain the metal in the pool.

(3) Surface tension. This is the force that makes it possible for a gently placed needle to be supported by the surface of water. This force is very important in retaining the molten metal in the pool of the joint. It also tends to draw a molten globule of metal into the pool once contact between the globule and the pool has been made. On the other hand, surface tension has no tendency to protect particles from the electrode tip through intervening space to the pool. Insofar as metal transfer is concerned, surface tension is of little importance except to retain the shape and the transferred metal in the pool.

(4) Electromagnetic forces. Pinch effect results from electromagnetic forces which arise from the high current passing through the metal globule at the electrode tip. This exerts a compressive force on the globule and tends to pinch or detach the globule from the electrode. Pinch effect was once thought to be important in metal transfer, but more recent investigators doubt that the force involved is sufficiently great to amount to much metal transfer.

(5) Gas expansion (fig 2-3). This theory explains metal transfer on the basis of gas pressure developed in the metal. The source of this gas is attrubuted to impurities. Heat causes the gas to expand and build up pressure. Either or both of two things may occur: (1) the gas is liberated at high velocity, it carries metal particles; or (2) the gas forms beneath the surface of the molten metal and, because of surface tension of the liquid metal, the gas expansion forms bubbles on the tip of the electrode. The bubble may expand until it contacts the molten pool on the work and short-circuits the arc, permitting transfer with the aid of surface tension from the pool on the base metal. On the other hand, gas pressure may burst the bubble, producing a fine spray of particles in the direction of the work. Considerable evidence has been accumulated to support this theory of metal transfer.

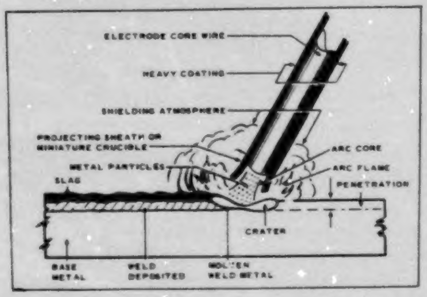


Fig 2-3. Characteristics of the shielded metal-arc.

d. Arc blow. There is one incident that frequently occurs when welding with direct current that you must understand so that you will recognize it when it occurs to be able to do something about it. This is arc blow, one of the more frequent annoyances with which the inexperienced welder must contend. When you are welding in corners, or are approaching an abrupt turn in welding, magnetism makes the arc unstable and difficult to control. The experienced welder will recognize this tendency and will take corrective measures before he loses control. Arc blow occurs when the electromagnetic field that surrounds every current-carrying conductor is distorted, a greater pull is exerted on one side than on the other. As a result, the arc tends to waver or blow out the side of the electrode, consuming the covering faster on that side. Your first warning will come when the magnetic force takes control of your arc and causes it to weave around like a recruit on his first liberty in J-ville. If you don't do something fast, the heat becomes so intense and the changes so rapid that you will lose your arc with an explosive burst that will carry away the molten metal from the weld. Arc blow can be overcome by changing the direction of current flow, by changing ground connections, by modifying the magnetic field with metal bars across the weld groove, by working towards the ground from any bend in the line of weld, or by tilting the electrode. In arc welding, the current travels first in one direction then in another, practically eliminating arc blow.

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EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The unit of force that tends to move electricity through a circuit is known as a(an)

   a. volt.
   b. watt.
   c. ampere.
   d. ohm.

2. The flow of electric current is called the

   a. volt.
   b. watt.
   c. ampere.
   d. ohm.

3. Insufficient penetration and heat escaping into the surrounding area is caused by

   a. too long an arc.
   b. too short an arc.
   c. setting on the welder to high.
   d. the wrong size electrode.

4. A dual control welder is one in which the desired current is selected by

   a. manual adjustment of the voltage and amperate rate.
   b. tapping the field coils at various points.
   c. automatically adjusting the voltage to meet the arc demand.
   d. tapping the generator core at various points.

5. Reverse polarity occurs when the work is _________ and the electrode is _________.

   a. positive -- positive.
   b. positive -- negative.
   c. negative -- positive.
   d. negative -- negative.

6. Straight polarity of a welding circuit is defined by the

   a. north pole.
   b. south pole.
   c. electrode being connected to the negative terminal.
   d. electrode being connected to the positive terminal.

7. The beneficial force which holds the filler metal to the bare metal in vertical welding is the

   a. surface tension.
   b. arc blow.
   c. gravity.
   d. gas expansion.

8. When welding in corners or approaching an abrupt turn, magnetism makes the arc unstable and difficult to control, you are experiencing

   a. arc blow.
   b. electromagnetic forces.
   c. gas expansion.
   d. gravity.

9. Three methods of overcoming arc blow are by changing the ground connections, tilting the electrode and

   a. increasing the current.
   b. decreasing the currect.
   c. changing the direction of current flow.
   d. decreasing the voltage.

Work Unit 2-2. CONSTRUCTION AND TYPES OF WELDS

LIST THE THREE PRINCIPLE PARTS OF A GROOVE AND FILLET WELD.

MATCH THE FIVE TYPES OF JOINTS WITH THEIR USES.

LIST THE FIVE TYPES OF WELDS.

A person's knowledge about his field is usually reflected by his vocabulary. It is essential that you have a good command of the technical vocabulary related to your work. This will make it possible to convey information and exchange ideas accurately. Here we are concerned with terms that apply more generally to all welding processes, namely, types of joints, welding positions, joint parts, weld parts, welding procedures, and sequences.

a. Nomenclature of the weld (fig 2-4). Although there are many kinds of welds, two that are of particular importance at this time are the groove and the fillet. Principal parts of both the groove and the fillet welds are the root, toe, and face.

(1) Root of the weld. The roots of the weld, as shown in the cross section, are the points at which the bottom of the weld intersects the base-metal surfaces.

(2) Toe of the weld. The toe is the junction between the face of the weld and the base metal

(3) Face of the weld. This is the exposed surface area of the weld, extending from toe to toe deposited by the arc of gas-welding process, on the side from which the welding was performed.

(4) Fusion zone. This is the region of the base metal that is actually melted.

(5) Reinforcement. This is the weld filler metal excess, on the face of the groove weld, which is an excess of the metal necessary for the specified weld size.

(6) Leg of a fillet weld. The leg is the distance from the root of the joint to the toe of the fillet weld. On the fillet weld there are two legs.

(7) Throat of a fillet weld. On the fillet weld there are two throats.

   (a) Actual throat. This is the shortest distance from the root of a fillet weld to its face.

   (b) Theoretical throat. This is the perpendicular distance between the hypotenuse of the largest right triangle that can be drawn within the fillet weld cross section and the beginning of the root of the weld.

(8) Size of weld. On an equal leg-length fillet weld, the size is designated by the leg length of the largest isosceles right triangle that can be drawn within the fillet weld cross section. For an unequal leg-length fillet weld, the size is designated by the leg length of the largest right triangle that can be drawn in the cross section of the weld. For example, if the legs are 1/4 and 3/8 inch, the size of the weld would be 1/4 x 3/8 inch. The size of a groove weld is the joint penetration (i.e., the depth of the bevel plus the root penetration when specified).

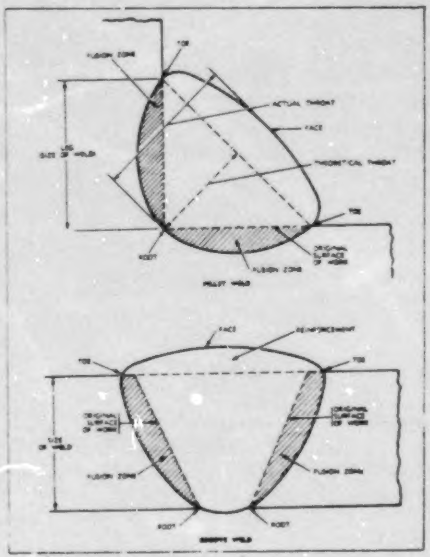

FUSION ZONE
TOE
ACTUAL THROAT
FACE
LEG
SIZE OF WELD
THEORETICAL THROAT
TOE
ROOT
ORIGINAL SURFACE OF WORK
FUSION ZONE
FILLET WELD
FACE
REINFORCEMENT
TOE
TOE
ORIGINAL SURFACE OF WORK
ORIGINAL SURFACE OF WORK
SIZE OF WELD
FUSION ZONE
FUSION ZONE
ROOT
ROOT
GROOVE WELD

Fig 2-4. Weld cross section.

b. Types and preparation of weld joints. There are five basic types of weld joints used in weld structures. Although there are many variations, every joint you weld will be one of these basic types. The properties of a welded joint depend on the correct preparation of the edges that are to be welded (fig 2-5). The edges should be prepared to permit fusion of the metals without excessive heat loss through radiation into the base metal. To prevent their inclusion in the weld metal, all mill scale, rust, oxides, and other impurities must be removed from the joint edges and surfaces. Also, with a properly prepared joint, a minimum amount of expansion and contraction will result. Joint preparation is governed by the type of joint being used, the thickness of the metal, the load which the weld will be required to support, and the means available for preparing the edges to be joined.

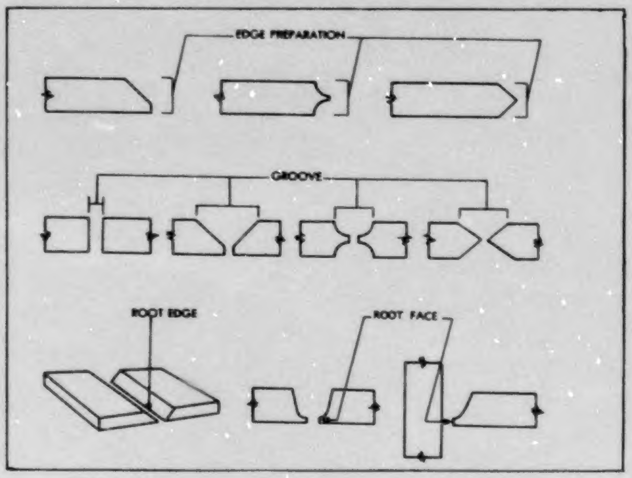
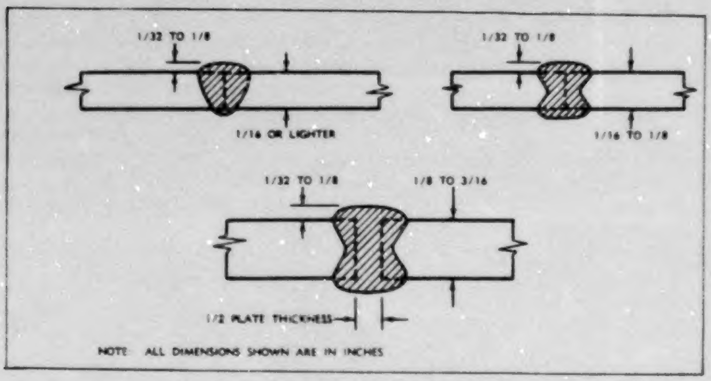
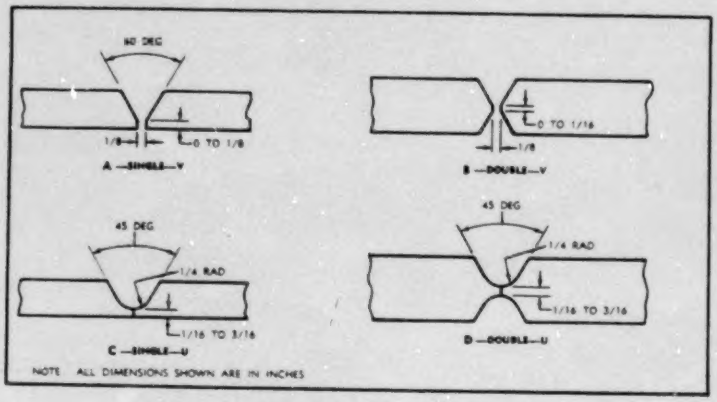


Fig 2-5. Edge preparation before welding.

(1) Butt joint (fig 2-6). This type of joint is used to join the edges of surfaces of two plates whose ends are lying in approximately the same geometric plane. The edges can be prepared by cutting or grooving with oxyacetylene, by shearing, machining, clipping, or grinding. Whatever the method used to prepare the edges, all scale, dirt, grease, and oxides must be removed. Joints shown in figure 2-6 are used in butt-welding light sections of sheet metal. Plate thicknesses of from 3/8 to 1/2 in. can be welded using the single V-type, or single U-type joint as shown in figure 2-6. The edges of still heavier sections would be prepared with a double V or double U. In general, butt joints prepared from both sides permit easier welding, produce less distortion, and insure better weld-metal qualities in heavy sections than a joint prepared and welded from one side.


1/32 TO 1/8
1/16 OR LIGHTER
1/32 TO 1/8
1/16 TO 1/8
1/32 TO 1/8
1/8 TO 3/16
1/2 PLATE THICKNESS
NOTE ALL DIMENSIONS SHOWN ARE IN INCHES

A. Butt joint, light sections.


60 DEG
1/8
0 TO 1/8
A —SINGLE—V
0 TO 1/16
1/8
B —DOUBLE—V
45 DEG
1/4 RAD
1/16 TO 3/16
C —SINGLE—U
45 DEG
1/4 RAD
1/16 TO 3/16
D —DOUBLE—U
NOTE ALL DIMENSIONS SHOWN ARE IN INCHES

B. Butt joint preparation for heavy sections.

Fig 2-6. Butt joints.

(2) Corner joint (fig 2-7). This is used to join two members located approximately at right angles to each other. The joint area in this case is between the edge of one member and the side or edge of the other member. It is used mostly in the construction of low pressure tanks, boxes, frames and other similar objects. The close-type joint (fig 2-7B) is used on light sheet metal where joint strength is not required. When welding this type with oxyacetylene, you use little, if any, filler metal. Usually the overlapping edge can be melted down to make the weld. In arc welding, only a very light bead is required. When the close-type joint is used for heavy plate, the lapped plate is V-beveled or U-grooved to permit penetration to the root of the joint. On heavy plate, the joint is welded from both sides, first from the outside, then reinforced from the back side with a seal bead.

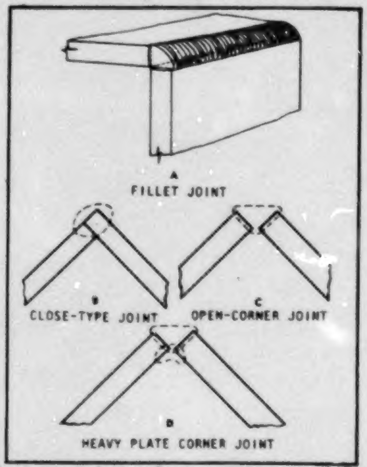

A
FILLET JOINT
B
CLOSE-TYPE JOINT
C
OPEN-CORNER JOINT
D
HEAVY PLATE CORNER JOINT

Fig 2-7. Corner joints for sheet and plate metal.

(3) Edge joint (fig 2-8). This type of joint is not very strong. It is principally used to join the edges of sheet metal and to weld reinforcing plates in flanges of I-beams or edges of angles. Two parallel plates (fig 2-8A) are joined together by means of an edge joint weld. On heavy plate, sufficient filler metal is added to fuse each plate edge completely and to reinforce the weld. Light sheets are welded by using joint B in figure 2-8. No edge preparation is required other than cleaning the edges and tack welding them in position. No filler metal is necessary as the edges are simply fused together. However, the joint shown in C, figure 2-8, is for welding heavy steel plates and requires that the edges be beveled so that good penetration and fusion of the sidewalls is obtained. This type of joint requires filler metal. Some typical applications of this type weld can be found on mufflers, tanks for liquids, housing, etc.

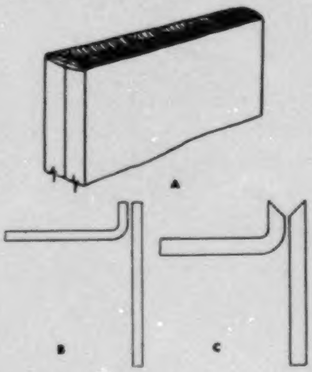


Fig 2-8. Edge joints for light and heavy plates.

(4) Tee joints (fig 2-9). This type of joint is used to weld two plates or sections whose surfaces are located approximately 90° to each other at the joint, but where the surface of one plate is not in the same plane as the other. Illustration A of figure 2-9 shows this type of plane tee joint welded from both sides. This type will require no edge preparation other than cleaning of the surfaces. B through E of figure 2-9 show edge preparation for typical tee joints. Plates with thicknesses up to 1/2 in. use the single-bevel joint. The double-bevel joint (fig 2-9C) is used on heavy plates or sections that can be welded from both sides and with plates having thickness of 1/2 inch or more. Where welding can be done only from one side of the plate, the single-J joint is used. The double-J joint is used for very heavy plates that can be welded from both sides. When welding these joints, you must take care to insure that there is good weld penetration into the root openings between the vertical and horizontal elements. This penetration is further aided by the root openings.

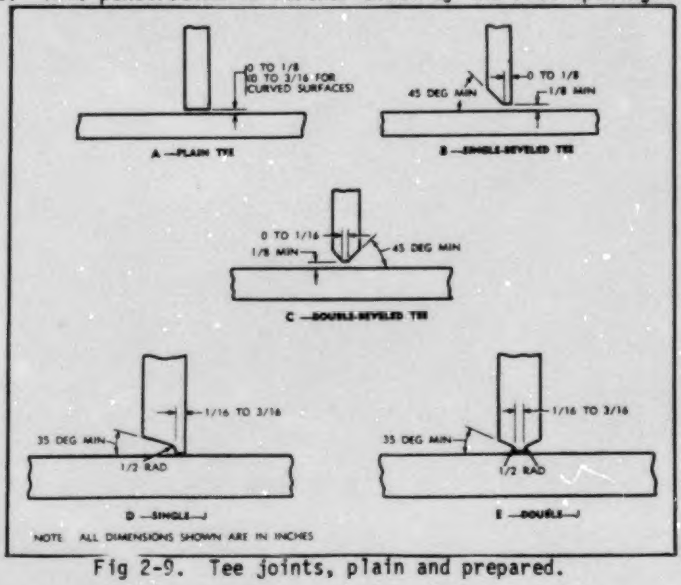

0 TO 1/8
(0 TO 3/16 FOR
CURVED SURFACES)
A —PLAIN TEE
0 TO 1/8
45 DEG MIN
1/8 MIN
B —SINGLE-BEVELED TEE
0 TO 1/16
1/8 MIN
45 DEG MIN
C —DOUBLE-BEVELED TEE
1/16 TO 3/16
35 DEG MIN
1/2 RAD
D —SINGLE—J
1/16 TO 3/16
35 DEG MIN
1/2 RAD
E —DOUBLE—J
NOTE ALL DIMENSIONS SHOWN ARE IN INCHES

Fig 2-9. Tee joints, plain and prepared.

(5) Lap joint (fig 2-10). This is used to join overlapping plates or sections so that the edge of one plate is welded to the surface of the other. Where the position of the joint doesn't permit welding from both sides, these joints may be made from one side only. However, full strength is not realized when welded in this manner. The double-lap joint, when welded on both sides will develop the full strength of the welded sections. Preparation for these two types involves nothing more than cleaning the surfaces of the welding areas. On an offset lap joint, where the overlapping plates must be in the same plane when joined and welded, the weld offers more strength than the single-lap joint, but preparation for the joint is more difficult.

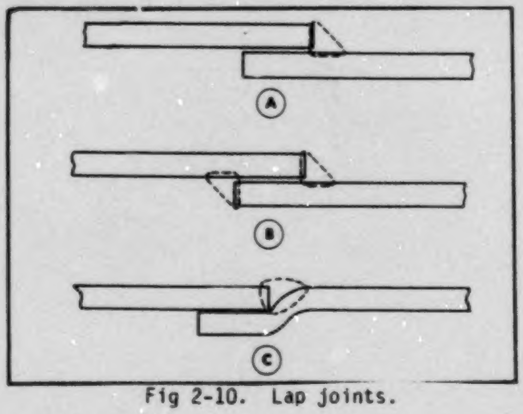


Fig 2-10. Lap joints.

c. Types of welds and welding positions. A weld is obtained by suitable heating, bringing together the surfaces to be joined, and usually the addition of molten filler metal between the joint surfaces. These surfaces are bound together by the use of weld patterns which have various names, the most common are bead, fillet, tack, groove, plug, and slot weld. These welds are applied in four different positions: overhead, flat, horizontal, and vertical. Both the weld types and positions will be discussed in the following paragraphs.

(1) Weld types.

(a) Bead weld. Usually a bead weld is made by depositing filler metal on an unbroken surface in a single direction. A bead may also be made without any externally added filler metals by simply forming a molten puddle in the base metal with a heat source and then moving the heat source in one direction. Bead welds are used principally on butt-type joints and to build up a surface. The cross section of a bead weld has an oval shape.

(b) Fillet weld. To join two sections that are at right angles to one another would require a fillet weld. Triangular in cross section, fillets are used to weld lap, tee, and corner joints. In addition to the face, toe, and root, a fillet weld has two parts with which you should be familiar: The legs and throat. A knowledge of the terminology relating to fillet welds is necessary so that you can understand precisely what size fillet weld is required by specifications for a given job.

(c) Tack weld. This is a short temporary weld deposit made to hold parts in proper alinement while they are being welded. Size of these welds are usually not specified, but they must not be more than 1 inch in length and they must be as small as practicable with the electrode being used. Tack welds must be incorporated into the final weld. If they are cracked or broken, they must be chipped out before final welding.

(d) Groove weld. This type of weld is made in specially prepared grooves between two sections to be joined. Most frequently used for butt joints, it is designed to provide the strength required with the minimum amount of deposited filler. The section of the groove weld design depends on the thickness of the plate being welded and accessibility to the joint being welded (i.e., access to both sides or only to one side). With few exceptions, the edges of the metal being joined by welding must be specially prepared, particularly for groove welds when the metal thickness exceeds 1/4 inch. This preparation involves beveling or grooving the edges in the joint areas. Figure 2-11 illustrates some of the standard groove welds. Joint design details revolve around the size of the groove and the space existing between the members of the joint. Specifications for joint designs are expressed in terms of bevel angle, groove angle, groove radius, and root opening. Figure 2-12 depicts these terms.

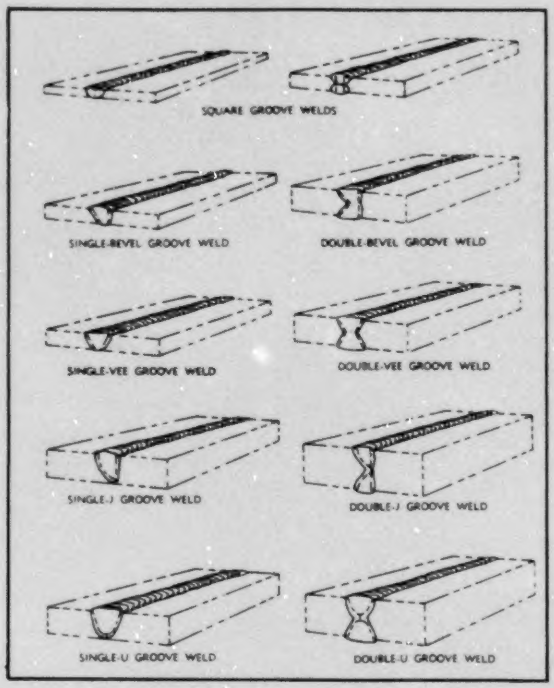

SQUARE GROOVE WELDS
SINGLE-BEVEL GROOVE WELD
DOUBLE-BEVEL GROOVE WELD
SINGLE-VEE GROOVE WELD
DOUBLE-VEE GROOVE WELD
SINGLE-J GROOVE WELD
DOUBLE-J GROOVE WELD
SINGLE-U GROOVE WELD
DOUBLE-U GROOVE WELD

Fig 2-11. Standard groove welds.

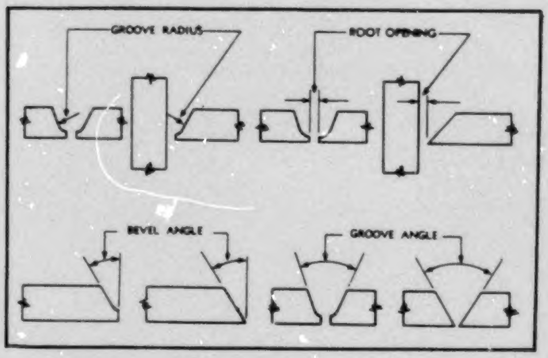

GROOVE RADIUS
ROOT OPENING
BEVEL ANGLE
GROOVE ANGLE

Fig 2-12. The bevel angle, groove angle, groove radius, and root opening of joints.

(e) Plug and slot welds (fig 2-13). A plug weld is a circular weld made through one member joining that member to another. It can be made through a hole punched or cut in the first member, or it can be made without punching a hole in the first member. It does not necessarily have to be filled completely with a filler metal. Normally plug welds are used to fill holes. The similarity between the slot weld and plug weld is the elongation of the hole in the slot weld. Slot welds permit development of required strength where fillets or butts are not economical.

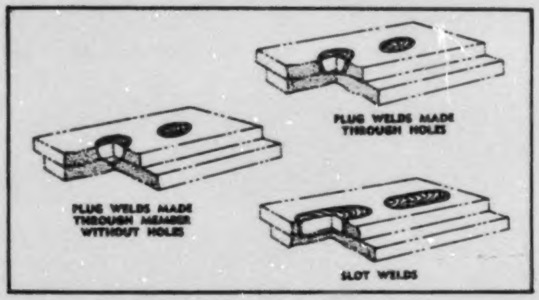

PLUG WELDS MADE THROUGH HOLES
PLUG WELDS MADE THROUGH MEMBER WITHOUT HOLES
SLOT WELDS

Fig 2-13. Plug and slot welds.

(1) Welding positions (fig 2-14). Welding must be performed in different positions. In engineer or motor transport maintenance facilities, welding in the flat position is not always possible. The positions for welding are flat, overhead, vertical, and horizontal. When welding is performed in the [illegible] position, the welder works from the upper side of the joint. In this position, the upper surface of the weld is in a plane parallel to the horizon. This is the case in both flat-position fillet and groove welds. In the horizontal position, the members being joined are in a vertical position, while the axis of the weld is horizontal. The face of a groove weld produced in the horizontal position is in a vertical plane. A horizontal-position fillet weld is slightly different from that of a groove weld. Welding a fillet in the horizontal position involves depositing filler metal on the upper side of a horizontal surface and against an approximate vertical surface. The face of the weld lies in a plane 45° to the surfaces of the parts being joined. When welding is performed in the vertical position, the axis of the weld is in a vertical plane, in both the groove and fillet welds, the face of the weld is parallel with the horizon, and in this position the weld metal is usually deposited in an upward direction. Welding performed in the overhead position is done from the underside of the joint. The axis of the weld is the same as that of the flat-position weld. Here too, the weld face is parallel with the horizon, but its orientation is approximately 180° from the face of a flat-position weld. The terms flat, horizontal, vertical, and overhead adequately describe the positions in which plates are welded.

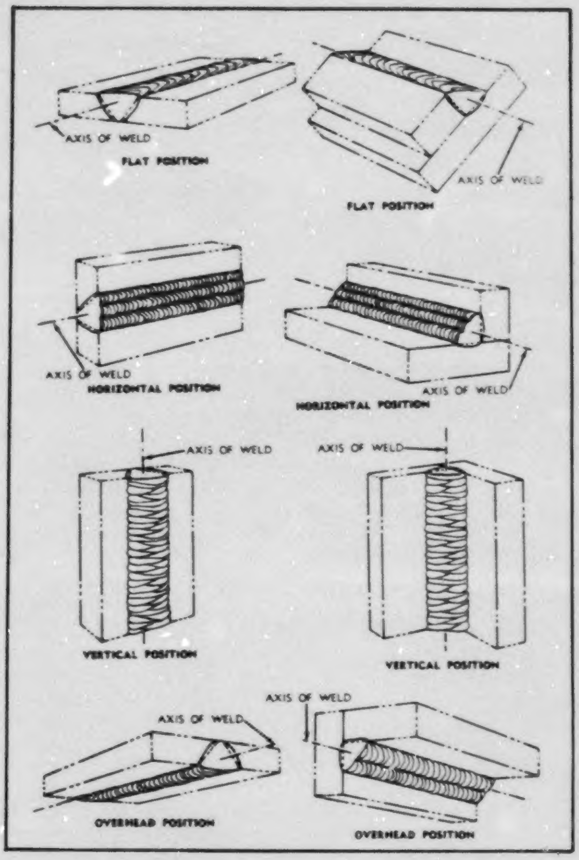

AXIS OF WELD
FLAT POSITION
AXIS OF WELD
FLAT POSITION
AXIS OF WELD
HORIZONTAL POSITION
AXIS OF WELD
HORIZONTAL POSITION
AXIS OF WELD
AXIS OF WELD
VERTICAL POSITION
VERTICAL POSITION
AXIS OF WELD
AXIS OF WELD
OVERHEAD POSITION
OVERHEAD POSITION

Fig 2-14. Welding positions.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. List the three principal parts of a groove and fillet weld.

   a. ______________________________
   b. ______________________________
   c. ______________________________

2. The point of the weld at which the bottom intercepts the base metal surface is the

   a. root of the weld.
   b. face of the weld.
   c. throat of the fillet.
   d. leg of the fillet.

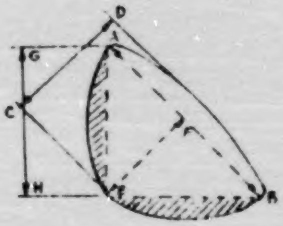
3. Define fusion zone.

   ____
   ____

4. The exposed surface area of a weld from toe to toe is the

   a. face.
   b. root.
   c. fusion zone.
   d. leg.

Note: Questions 5-7 refer to the diagram below.



5. Which line indicates the actual throat of the weld?

a. A - B	c. E - F
b. C - D	d. G - H

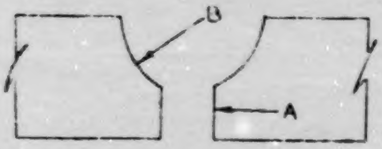
6. Which line indicates the size of the weld?

a. A - B	c. E - F
b. C - D	d. G - H

7. Which line indicates theoretical throat of the weld?

a. A - B	c. E - F
b. C - D	d. G - F

Note: Questions 8-9 pertain to the diagram below.



8. The area indicated by line A is known as the

a. face.	c. edge.
b. angle.	d. opening.

9. The area indicated by line B is the

a. bevel angle.	c. root face.
b. groove angle.	d. groove radius.

10. To join two sections at right angles to one another, you would use a _________ weld.

a. tack	c. fillet
b. plug	d. seamf

11. In welding, overhead, flat, and horizontal are considered to be

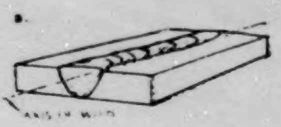
a. techniques.	c. methods.
b. positions.	d. difficulties.

12. A weld that is made through one member to join the two members together is called _________ weld.

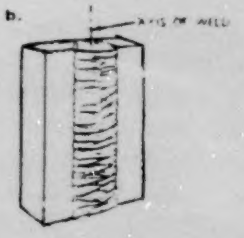
a. flash	c. spot
b. fillet	d. plug

13. Select the correct diagram indicating a horizontal weld.

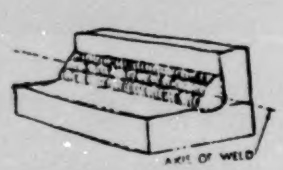
a.



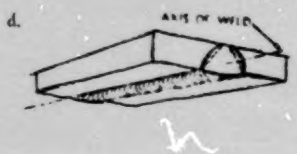
b.



c.



d.



14. List the five types of welds.

a.
b.
c.
d.
e.

Matching: Match the five types of joints in column 1, (15 - 19), with their correct uses.

Column 1	Column 2
15. Butt	a. To join two edges of sheet metal
16. Corner	b. To join two plates at a 90° angle to each other
17. Edge	c. To join two edges of surfaces of two plates located approximately in the same geometric plane
18. Tee	d. To join two members located at right angles to each other
19. Lap	e. To join overlapping plates

Work Unit 2-3. ARC-WELDING MACHINE ACCESSORIES

DEFINE PERSONAL PROTECTIVE DEVICES.

LIST THE EIGHT TOOLS AND EQUIPMENT USED IN ARC-WELDING.

STATE THE BREAKDOWN OF AN ELECTRODE.

a. Welding cables. The cables which conduct the welding current from the power source to the weld and then back to the source must have ample current-carrying capacity, good insulation, provisions for coupling, flexibility, and durability. A highly flexible cable is used between the electrode holder and the welding machine. The ground cable, which connects the work and the machine, does not have to be as flexible as the cable attached to the electrode holder. Two factors determine the size of the welding cables selected for use, the amperage rating of the machine being used and the distance between the work and the machine. if amperage and distance are increased, the size of cable must be increased. A cable which is too small in relation to the amperage being used will become overheated. Likewise, a cable too small in relation to the distance involved will not carry sufficient current to the arc without becoming overheated. On the other hand, cable that is too large is more difficult to handle. Cables that are suitable for the type of equipment that you are using are furnished with that particular type of machine. If you have more than one size cable available to you, the information in figure 2-15 will serve as a guide for proper section.

Machine rating (in amperes)	Cable lengths					
	Up to 50 feet		50 to 100 feet		100 to 250 feet	
	Size No.	O. D. (inch)	Size No.	O. D. (inch)	Size No.	O. D. (inch)
Up to 150 -------	2	0.604	2	0.604	2	0.604
200 -------------	2	.604	1	.644	2/0	.754
300 -------------	0	.694	2/0	.754	4/0	.959
400 -------------	2/0	.754	3/0	.827	4/0	.959
600 -------------	2/0	.754	4/0	.959	4/0	.959

Fig 2-15. Recommended cable sizes.

As a rule, the shorter the cable length between the work and the machine, the better. It is recommended that the maximum length of 4/0 cable for a 400-ampere welder be not over 150 feet. The longer the cable used, the greater the cable size required, and with the increased size you lose the ease of handling of the cable. So instead of increasing the size of the cable, move the machine closer to the work.

b. Electrode holder (fig 2-16). This is essentially a clamping device for holding the electrodes. It is provided with a hollow insulated handle through which the welding cables pass to connect with the clamp. The advantage of this insulated handle is that it can be touched to any part of the work without danger of a short circuit. The clamping device is made of an alloy which is a good conductor of electricity and durable under high temperatures and constant use. It is designed to permit the electrode to be held in any position and also permit easy change of electrodes. Holders are made in a variety of designs and sizes, each intended for use within a given range of electrode wire diameters and within a maximum welding-current amperage. Thus, a larger holder is required for welding with a machine having a 300-amp rating rather than a 100-amp unit. If the holder is smaller than required for the particular amperage, it will overheat. The holder selected should be large enough to do the job, but not larger than necessary. You should be able to handle it with relative ease.

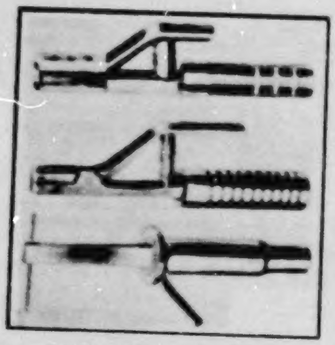


Fig 2-16. Electrode holders.

c. Personnel protective devices. The need for personnel protection arises from the fact that during a welding process there is intense light, reflected glare, radiated heat, and flying particles of hot metal. Any device that protects the welder from these hazards is important. Consider eyes first. Injury to other parts of the body may be incapacitating and painful, but usually body tissue is capable of repairing itself without permanent injury. Not so the eye. Unfortunately, loss of sight is almost always permanent. For this reason, eye protection is of the utmost importance, not only to the welder, but to others who may be in the vicinity of the welding operation. The type of eye protection used depends on the type and position of the welding. Rigid-bridge, spectacle-type goggles or eyecup-type goggles with suitable filter lenses are used during gas-welding operations. When welding is done at or above the eye level, only eyecup-type goggles which conform to the contour of the face should be worn. For arc welding, a welding helmet having a suitable filtered lens is necessary. When these operations are performed in areas where other welding is going on, the welder should wear spectacles with side shields or eyecup goggles beneath the welding helmet to shield the user from glare and radiation from adjacent work. A filter lens may be used, however, the sum of the filter lens from the goggles and the welding helmet should be equal to the filter lens number that is recommended as being safe. Helmets, hand shields, and goggles used for welding are of a nonflammable insulating material. They are fitted with a protective color filter and a clear cover glass, the purpose of these is to protect the color lens from becoming pitted from flying sparks and weld spatter. The lenses are fitted in such a way as to provide easy removal and replacement without any tools. These colored lenses are available in different shades, and the shade number selected depends on the purpose for which eye protection is required and somewhat on the preference of the wearer. Remember though, these lenses serve two purposes: they reduce the intensity of the visible light to a point where there is no glare, and they protect the eyes from harmful infrared and ultraviolet radiations emitted from the arc or the flame. Consequently the shade filter selected should not vary more than two shades from the numbers recommended in figure 2-17. Eye protection for yourself is essential, but you also have a responsibility to others. The flashes from the arc are liable to cause temporary and painful eye burns if protection is not provided. Areas in which welding is done should be painted flat black to prevent flickering reflections. If possible, the area should also be enclosed by a booth or screens painted with a nonreflecting color. Protection of the other parts of the body as well as the eyes is also important during welding operations. A variety of protective clothing has been designed, is available, and should be used whenever you are involved in any welding operation. Like the eye protectors, the clothing selected will vary with the nature of the work. During any welding or cutting, you should wear flameproof gauntlets. For gas welding, you should use the 5-finger glove; for arc welding, the 1-finger mitten. In common with other leather protective clothing for welders, gloves are made from split cowhide which has been chrome-tanned. This process conditions the leather, and makes it more effective against heat and more resistant to heat-deteriorating effects. Both types will protect your hands against heat and metal spatter. Many light gas-welding jobs require no more protection than gloves and goggles. Medium and heavy gas welding, all electric-arc welding, and any job in the overhead welding position, require specially designed clothing made of leather or asbestos material to protect you against radiated heat, splashes of hot metal, or sparks. This clothing consists of aprons, sleeves, combination sleeves and bib, jackets, and overalls, which afford a choice of protection depending on the nature of the welding operation. Sleeves provide satisfactory protection for welding operations at floor or bench level. Cape and sleeves are particularly suited for overhead welding because the cape protects the back of the neck, top of the shoulders, and upper parts of the chest and back. Use of the bib in combination with sleeves and cape gives added protection to the chest and abdomen in cases where protection to the back is not required. The jacket should only be worn when it is necessary to protect the entire upper half of the body, such as when welding in close proximity to several other welders. Aprons and overalls provide protection to the legs and therefore are suited for welding operations on the deck. When welding in the overhead position, welders should wear leather caps under their helmets to prevent head burns. When there is danger from sharp or falling objects, hard hats or head protectors attached to form part of the helmet should be used. If leather protective clothing is not available, woolen rather than cotton garments should be used, since wool does not ignite as readily as cotton and affords better protection from the heat. As with any electrical device, the danger of shock and electrocution during arc-welding operations is always present. Before preventive maintenance or repairs of any nature are performed on the welder, the electrical system must be deenergized; also, when the welding cables are attached to the welder. At no time should welding be performed in damp or wet areas unless it is an absolute emergency. Then the operator should be protected from the ground surface by the use of rubber insulating mats or dry wooden duckboards. When replacing electrodes in the electrode holder, move the holder far enough away from the material being welded so that there is no danger of accidentally grounding the holder, electrode, and the work all at the same time while the electrode is in your hand. Generally speaking, all rules governing the safe handling of electrical apparatus should be practiced and observed at all times. Keep your mind on the business at hand; don't be daydreaming about tonight's liberty run, or you may not be making it.

Shade No.	Operation
Up to 4 ------------	Stray light from nearby welding and cutting operations and from electric spot welding
5 ------------------	Light gas cutting and welding.
6 ------------------	Gas cutting, medium gas welding, and arc welding up to 30 amps.
8 ------------------	Heavy gas welding and arc welding between 30 and 75 amps.
10 -----------------	Arc welding between 75 and 200 amps.
12 -----------------	Arc welding between 200 and 400 amps.
14 -----------------	Arc welding exceeding 400 amps.

Fig 2-17. Recommended filter lenses for welding operations.

d. Tools and equipment. In addition to welding machines, flexible cables, electrode holders, and protective devices, the arc welder also has a need for chipping hammers, wire brushes, welding tables, backup bars, and other items of equipment to properly start and finish a welding operation. As you start to weld, you will notice a slag deposit appear on the surface of the weld face. Before you can do any further welding, these deposits of scale, oxides, and slag must be removed by using a chipping hammer (fig 2-18) to break the scale and a wire brush to further clean the weld surface area. In order to have good, sound, solid welds it is necessary that the weld area be clean or gas pockets will form in the weld area and result in inferior weld beads. When welding thin aluminum, and making certain types of joints, you will find it necessary to use backup bars (fig 2-19). These can be either blocks, strips, or bars of copper or cast iron. For welding aluminum, nickel, etc., backup plates are used because these metals become weak just before the melting point is reached. These plates are not only a reinforcing measure, but act as chill plates in that they dissipate the heat away from the weld area. Because of its good conducting quality, copper is particularly effective for use as backup plates. During arc-welding operations, it is necessary that a good ground contact be maintained and that the work be as stable as possible. The use of C-clamps for clamping the work in position is very good ror this. C-clamps come in various sizes and should be selected according to the nature of the work.

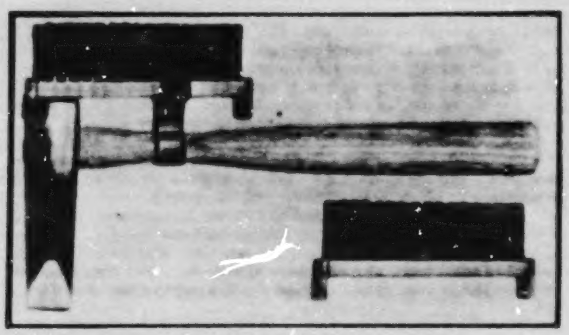


Fig 2-18. Chipping hammer with attached brush.

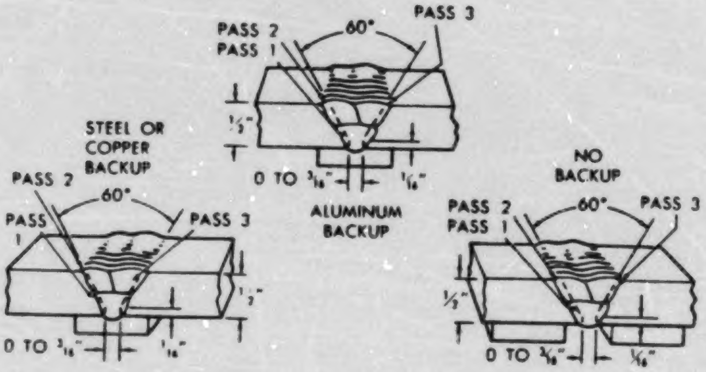


Fig 2-19. Using backup bars to weld aluminum.

e. Electrodes (fig 2-20). The bulk of your metal-arc welding work will be done manually with the shielded metal-arc. The arc develops an intense heat, melting the base metal and forming a molten pool of metal in a localized area. At the same time, the electrode tip melts and metal particles from the tip are carried across the arc into the molten pool. The arc and molten pool are shielded from the oxidizing effect of atmosphere by the decomposition of the electrode covering. Electrodes suitable for shielded metal-arc welding of all kinds and thicknesses of metal alloys are manufactured in a large variety of types and sizes. Some of these electrodes require an ac welding current; others are designed for use with dc. Still others may be used with either ac or dc welding equipment. Electrodes are classified by the American Welding Society (AWS) and American Society for Testing Materials (ASTM). Each type of electrode is classified by a number which indicates the welding positions to which it may be applied and a general discription mentioning the type of covering, current, and polarity recommended. Figure 2-20 illustrates the manner in which electrodes are classified by the American Welding Society. To understand these classifications, let us look at how they are arranged. Take the classification number E6010. The E represents the word electrode. The first two numbers, in this case 60, refer to the tensile strength of the deposited weld metal in 1,000 pounds per square inch (psi). In this case, the electrode would have a pull strength of 60,000 psi. The third number represents the positions in which this electrode may be applied. Number 1 indicates all positions (overhead, flat, vertical, and horizontal). Number 2 designates a greater restriction of welding positions since it can be used only in the horizontal fillet and flat positions. Number 3 indicates the electrode can be used only in the flat position. The fourth number in the classification system indicates subgroups, of which there are seven. This digit shows some characteristics are as follows:

0 = Use dc current with reverse polarity, except that in cases where the last two digits are 20 or 30, e.g., 6020 or 6030, either current or polarity may be used.
1 = Use ac or dc current with reverse polarity. Gives deep penetration with a high quality weld.
2 = Use dc current, straight polarity or ac current only. Gives medium penetration with medium-quality welds.
3 = Ac or dc current, either polarity with slight penetration, medium-quality welds.
4 = Use ac or dc current, medium penetration and a fast rate of metal deposit
5 = Dc current with reverse polarity. Moderate penetration and produces high-quality welds.
6 = Ac current, reverse polarity, high-quality welds with about the same qualities as number 5.

Covering	Electrode classification No tory welds in positions shown-	Capable of pro- during satisfac-	General description
Light coating	E4510[b]	F, V, OH, H	Sulcoated or light-coated electrode for use in manual welding. but sometimes used for machine welding.
	E4520[b]	H-fillets, F	Light-coated electrode for use with high-speed machine welding. May be used for manual welding.
Heavy covering	E6010[c]	F, V, OH, H	For use only with dc reversed polarity (electrode positive).
	E6011[c]	F, V, OH, H	For use with ac or dc reversed polarity (electrode positive).
	E6012[c]	F, V, OH, H	For use with dc straight polarity (electrode negative) or ac.
	E0613[c]	F, V, OH, H	For use with ac or dc straight polarity (electrode negative) on light-gage metal.
	E6020[b]	H-fillets, F	For use with dc straight polarity (electrode negative) or ac for horizontal fillet welds and dc (either polarity) or ac for flat-position welding.
	E6030[c]	F	For use with dc (either polarity) or ac.
Heavy covering	E7010[d]	F, V, OH, H	For use only with dc reversed polarity (electrode positive).
	E7011[e]	F, V, OH, H	For use with ac or dc reversed polarity (electrode positive).
	E7012[d]	F, V, OH, H	For use with dc straight polarity (electrode negative) or ac.
	E7020[d]	H-fillets, F	For use with dc straight polarity (electrode negative) or ac for horizontal fillet welds and dc (either polarity) or ac for flat-position welding.

Fig 2-20. AWS electrode specifications.

Covering	Electrode classification No	Capable of produring satisfactory welds in positions shown-	General description
	E7030[d]	F	For use with dc (either polarity) or ac.
Heavy coating	E8010[e]	F, V, OH, H	For use only with dc reversed polarity (electrode positive).
	E8011[e]	F, V, OH, H	For use with ac or dc reversed polarity (electrode positive).
	E8012[e]	F, V, OH, H	For use with dc straight polarity (electrode negative) or ac.
	E8020[e]	H-fillets, F	For use with dc straight polarity (electrode negative) or ac for horizontal fillet welds and dc (either polarity) or ac for flat-position welding.
	E8030[e]	F	For use with dc (either polarity) or ac.
Heavy covering	E9010[f]	F, V, OH, H	For use only with dc reversed polarity (electrode positive).
	E9011[f]	F, V, OH, H	For use with ac or dc reversed polarity (electrode positive).
	E9012[f]	F, V, OH, H	For use with dc straight polarity (electrode negative) or ac.
	E9020[f]	H-fillets, F	For use with dc straight polarity (electrode negative) or ac for horizontal fillet welds and dc (either polarity) or ac for flat-position welding.
	E9030[f]	F	For use with dc (either polarity) or ac.
Heavy covering	E10010[g]	F, V, OH, H	For use only with dc reversed polarity (electrode positive).
	E10011[g]	F, V, OH, H	For use with ac or dc reversed polarity (electrode positive).
	E10012[g]	F, V, OH, H	For use with dc straight polarity (electrode negative) or ac.
	E10020[g]	H-fillets, F	For use with dc straight polarity (electrode negative) or ac for horizontal fillet welds and dc (either polarity) or ac for flat-position welding.
	E10030[g]	F	For use with dc (either polarity) or ac.

a/ The abbreviations, F, H, V, OH, and H-fillets indicate welding positions as follows: F - flat, H - horizontal, V - vertical, OH - overhead, H-fillets - horizontal fillets.

b/ E45 series. - Minimum tensile strength of deposited metal 45,000 psi in nonstress-relieved condition.

c/ E60 series. - Minimum tensile strength of deposited metal 60,000 psi in stress-relieved condition; 62,000 psi in nonstress-relieved condition.

d/ E70 series. - Minimum tensile strength of deposited metal 70,000 psi in stress-relieved condition.

e/ E80 series. - Minimum tensile strength of deposited metal 80,000 psi in stress- relieved condition.

f/ E90 series. - Minimum tensile strength of deposited metal 90,000 psi in stress-relieved condition.

g/ E100 series. - Minimum tensile strength of deposited metal 100,000 psi in stress-relieved condition.

Fig 2-20. AWS electrode specifications (continued).

In general, the materials in the coating of a shielded-arc electrode determine the polarity and also control penetration. E6010 gives greater penetration than does E6012 under identical conditions. This does not mean that greater penetration is obtained with reverse polarity; it merely means that coatings of the type used on E6010 class usually result in electrodes that give greater penetration. Electrodes operating on either polarity usually melt at a higher rate when the electrode is negative (straight polarity). Therefore, a higher travel speed is ordinarily employed, resulting in less penetration. Ordinarily, knowing that a straight polarity electrode gives less penetration is sufficient.

(1) All-position electrodes. There are two subtypes under this group: reverse-polarity all-position electrodes, and straight-polarity all-position electrodes. The reverse-polarity shielded-arc electrodes have a coating of appreciable thickness which is comprised essentially of cellulosic materials (wood, flour, etc.) The straight-polarity all-position electrodes also have an appreciable coating thickness, but the coating in this instance is made up of cellulosic and mineral materials. The lesser coating thickness, together with the arc action created by these materials, makes it possible to weld in the flat, horizontal, vertical, and overhead positions with electrodes of diameters up to and including 3/16 inch.

(a) E6010 all-position, direct-current, reverse-polarity electrode. The E6010 all-position, dc, reverse-polarity electrode is the best adapted of the shielded-arc types for vertical and overhead welding. It is, therefore, the most extensively used electrode for the welding of steel structures which cannot be positioned and which require considerable welding in the vertical and overhead positions. The quality of the weld metal is of a high order and the specifications for this classification are correspondingly rigid. Electrodes of this type are unable only with direct current on reverse polarity (electrode positive). The essential operating characteristics of the electrode as follows:

Strong and penetrating arc enabling penetration beyond the root of the butt or fillet joint.

Quickly solidifying weld metal enabling the deposition of welds without excessive convexity and undercutting.

Low quantity of slag with low-melting and low-density characteristics so as not to interfere or become entrapped when oscillating and whipping techniques are used.

Adequate gaseous atmosphere to protect molten metal during welding.

(b) E6011 all-position, alternating-current electrode. The E6011 all-position; ac electrode is intended to have similar operating characteristics and to be used for similar welding applications as E6010, but with ac.

(c) E6012 all-position, direct-current, straight-polarity electrode. The E6012 type electrode is often referred to as a "poor fitup electrode" because of its ability to bridge wide gaps in joints. It is particularly well adapted for single-layer welding or horizontal fillets. This type is very extensively used in steel fabrication because it offers economy due to ease of use and high welding speeds. The usual operating characteristics of this type of electrode are listed below:

Suitable for use with dc with either straight (electrode negative) or reverse (electrode positive) polarity, and with ac. Straight polarity is preferred because of a more direct and stable arc.

Adequate penetration in order to reach the root of fillet and other joints, but not as deep a penetration as with E6010, in order to enable the filling of wide gaps without burning through. The small diameters, such as 3/32 and 1/8 inch, are especially adapted for sheet-metal welding without tendency to burn through the sheets.

The slag is more abundant and covers more of the pool than those of E6010 types, but it is not as abundant or as fluid as those of E6020 and E6030 types. The slag solidifies very rapidly just below the freezing point of the metal and is generally dense and close fitting to the deposit.

The molten metal may be considered slightly more fluid than that of the E6010 type, but not to the extent that this electrode cannot be used in all-position welding. The molten metal and slag characteristics control the shape of the weld deposit and make the electrode especially suitable for horizontal fillet welding, producing flat or slightly convex beads without undercutting. Many of the electrodes of this type are suitable for vertical welding in the downward direction, although for some purposes, the penetration and throat thickness are insufficient. In vertical welding in the upward direction, small welds are more convex with wider spaced ripples than with the E6010 electrodes.

(d) E6013 all-position, alternating-current electrodes. The E6013 type of electrode is intended to be similar to E6012 type, but with improved arc characteristics with ac. These improvements are necessitated by the fact that many types of ac machines have a relatively low open-circuit voltage and demand easily ionized coating materials in the electrode for satisfactory operation. The applications for this electrode are the same as for E6012.

(2) Flat-position electrodes. Electrodes of this type are covered by classifications E6020 and E6030. These electrodes usually have a very heavy mineral coating consisting principally of metallic oxides, asbestos, clay, or silicates. These electrodes depend upon the slag for the shielding action. They are used with high currents, and the molten metal is very fluid. This combination of extreme fluidity of the molten metal, together with the large amount of slag, makes it practically impossible to weld vertically and overhead with these electrodes.

(a) E6020 horizontal fillets and flat positions, direct or alternating current. The E6020 electrode is designed for the production of flat or concave surface fillet welds in the flat or horizontal positions, with either dc or ac. This electrode has numerous applications where very high quality weld metal is required and where work is positioned, such as in the fabrication of pressure vessels, machine bases, gun mounts, and similar structures. The essential operating characteristics are as follows:

Usable with either ac or dc. It is mainly used with ac but when used with dc, straight polarity is preferred, especially for the welding of horizontal fillets.

The main requirement of the electrode is to produce horizontal fillets of flat or concave surface without undercutting. This necessitates that the molten metal and slag be comparatively fluid, that the metal be quick-freezing, and that the slag continuously cover the back portion of the pool and actually wet the molten metal.

Slags of this type are not quick-freezing, but remain as a plastic glass for some time after the molten metal has solidified. The slag and metal are both too fluid to permit general welding in vertical or overhead positions.

While specifically designed to meet horizontal fillet welding requirements, the electrode is also adapted to the welding of butt or other flat-position joints.

The physical properties of welds are of a very high order, especially in elongation. Radiographs show that properly made welds are practically perfect.

(b) E6030 flat-position, direct or alternating current. The E6030 type overlaps with E6020, but particular attention is given to its use in butt welds. It differs from E6020 in that it produces a smaller amount of slag and a less fluid slag and a less fluid slag, thus decreasing the possibility of slag interference and deep grooves. It is not as suitable for horizontal fillet welding due to insufficient slag coverage of the molten pool. Electrodes of this type are used in flat-position welding of pressure vessels and numerous other objects. It is necessary that the weld deposit meet the highest standards of X-ray and physical property requirements. Essential operating characteristics are listed below:

This electrode is adaptable for use in narrow- or wide-groove butt joints, providing adequate slag coverage for weld shape and protection, but not slag interference with the arc.

Slag must wet metal surface and produce a concave weld within the confines of the groove.

The slags are porous and, therefore, are very easy to remove. They have a hardening range extending considerably below the freezing point of the steel deposit.

(3) Electrode classification by bead shape. Mechanics will arc-weld various types of steel more often than the nonferrous metals. Therefore, the following method of classifying electrodes for steel welding should prove very useful. The classification is based on the shape of the bead which is obtained when arc-welding with a particular electrode.

(a) Flatbead type (class E6010). The E6010 flathead type may be classified as a general-purpose electrode because it is used for a wide variety of work, and it possesses high average physical characteristics. It has a heavy coating and is best suited for direct current with electrode positive. In smaller sizes (3/32 in. and smaller) the E6010 is suitable for use in all positions. The 3/16-in. size is specially made for all positions. It is suitable for fillets, deep grooves, and all types of joints in all sizes. It has deep penetration qualities and is used very satisfactorily on square butt joints where the electrodes actually scarf or melt the plates. It produces a rather flat bead of general type as shown in figure 2-21.

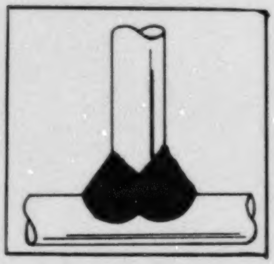


Fig 2-21. Flat bead produced by class E6010 electrode.

(b) Convex-bead type (class E6012). The class E6012 convex-bead type of electrode has a heavy covering and gives best results with direct current with the electrode negative, or it may be used satisfactorily with alternating current. Sizes 3/32 in. and smaller are suitable for all positions, although 3/16 in. often is used in all positions, and in larger sizes for welding in flat positions. It may be used for fillet welding, single, or multiple pass, and it can be used for butt welds of the V- or U-groove type. Because of its disposition characteristics and ability to build up, it is frequently used where fitup is poor or where a small admixture of base metal is desired. It produces an exceptionally smooth bead which is somewhat convex as indicated in figure 2-22.

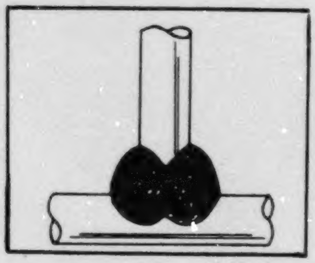


Fig 2-22. Smooth, convex bead produced by class E6012 electrode.

(c) Concave-bead type (class E6030). The concave-bead type of electrode has a heavy covering and can be used with direct current and with the electrode either positive or negative, or it can be used with alternating current. It is used in the flat position only, and it is not suitable for vertical or over-head work. This type is used for fillets or butt joints of the V- or U-groove type. It flows very readily, producing a heavy slag cover on the weld. It is sometimes known as the "hot-rod" type. It produces a very smooth bead, slightly concave, as shown in figure 2-23 when welded in grooves or position fillets, but not so concave when fillets are horizontal.

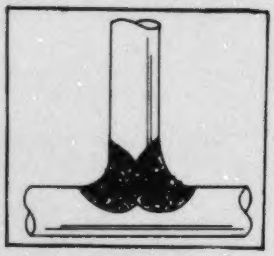


Fig 2-23. Smooth, concave bead produced by classes E6020 and E6030.

EXRCISE: Answer the following questions and check your responses with those listed at the end of this study unit.

1. Select the two factors used to determine the size of welding cables to be used while welding.

   a. Type of metal and the voltage used
   b. Amperage rating of the welder and distance from the work
   c. Distance from the work and voltage output
   d. Type of metal welded and type of electrode used

2. Define "Personal Protective Devices".

   ____

   ____

3. The clear cover glass in a welding helmet is used to

   a. protect the eyes from sparks.
   b. filter light rays.
   c. protect the colored lens.
   d. improve vision during welding.

4. If you must weld and appropriate protective clothing is not available, the next safest clothing to wear is

   a. cotton.
   b. silk.
   c. rayon.
   d. wool.

5. An area, which is utilized for arc welding, should be painted

   a. Marine Corps green.
   b. flat olive drab.
   c. flat black.
   d. camouflage.

6. When you are welding with an amperage rate of 150, you should use a number ______ shaded lens.

   a. 5
   b. 6
   c. 8
   d. 10

7. The polarity to be used with a specific type of electrode is determined by the

   a. type of welding machine being used.
   b. size of the electrode.
   c. manufacture of the electrode.
   d. electrode coating.

8. An E6012 electrode produces a _________ shaped bead.

a. flat
b. concave
c. convex
d. round

9. The electrode, which is preferred for filling wide gaps in a joint, is

a. E6010.
b. E6011.
c. E6012.
d. E6013.

10. The purpose of thoroughly cleaning the area to be welded is

a. so the welder can see the joint.
b. to prevent gas pockets from forming.
c. to justify the amount of time it takes to complete a job.
d. to assist in painting after the welding is completed.

11. State (or break-down) the 5 digit number which appears on an electrode.

a. ______________________________
b. ______________________________
c. ______________________________
d. ______________________________

12. List the nine items of tools and equipment that are used in arc-welding.

a.
b.
c.
d.
e.
f.
g.
h.
i.

Work Unit 2-4. ARC-WELDING MACHINES

IDENTIFY THE TWO TYPES OF ARC WELDING MACHINES.

MATCH THE PURPOSE OF THE GAUGES AND CONTROLS ON THE LM-62 WELDER WITH THEIR NAMES.

In this major category of welding equipment, there are two broad types of machines, those that use direct current (dc), and those that use alternating current (ac). Direct current, as you recall (from para 2-1), refers to a steady flow or stream of electrons in one direction. Alternating current, on the other hand, refers to a 2-way flow of electrons, first in one direction and then in the other. Arc-welding equipment differs not only as to ac or dc, but in a number of other ways. For example, a given piece of equipment may be stationary or portable, single or multiple-operator, motor-generator, gasoline or diesel engine-driven, a resistor unit, or a transformer-type unit. In addition, the several types also vary in their heat output, that is, the number of amperes they deliver at applicable arc voltages. Regardless of the type of unit, the current source must be sufficient to strike and hold a stable arc suitable for welding. The current is obtained principally from one of the sources discussed below.

a. Direct-current welders. The first source of current is obtained from an existing dc power source used in conjunction with resistors to reduce the voltage and current to the amount required for welding (fig 2-24). This source is used with a line-resistor unit as a part of the welding system. This source must not exceed 120 volts. A greater voltage constitutes a hazard to the operator. A second power source is a dc generator with variable voltage characteristics; that is, the generator is so designed that it delivers a voltage high enough to establish the arc and then reduces this voltage as required to maintain the arc during welding. A third source for welding current is a rectifier which converts an ac powered source to a dc welding current. This source does not depend on rotating parts to provide a suitable current for welding. Direct-current welders have the advantage of being suitable for use on all metals. They produce very satisfactory results on the material, which requires low-current settings. The machine that is most commonly used is the motor-generator type operated by a constant-speed governed diesel engine mounted on a trailer-type chassis. Some machines have a switch for changing polarity. Others require that you reverse the welding cables to change polarity. A pushbutton switch located on the control panel permits easy stopping and starting. A voltmeter and ammeter or a combination of both permits the operator to set the machine at a prescribed output. Current ratings represent the amount of current that the machine will generate continuously for 1 hour without exceeding a specified temperature rise.

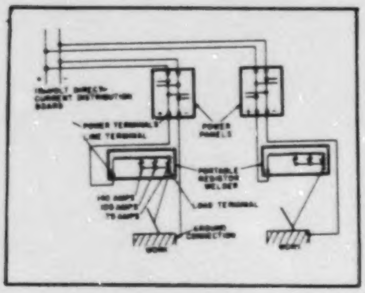


Fig 2-24. Connection of line-resistor welders to a 115-volt, dc, 2 wire distribution board--reverse polarity.

(1) Model LM-62 welding set, arc, trailer-mounted (fig 2-25). This is the welding set presently in use by the Marine Corps. It is a diesel-engine-driven, self-contained direct current welder which consists of arc-welding equipment, but it also provisions for gas-welding and cutting torches. The welder is totally enclosed in a sheet-metal housing mounted directly on a modified M200A1 trailer. Hinged doors provide access to the engine, gas-welding equipment, and the various engine and arc-welding controls and indicators. In front of the enclosure are provisions for three gas cylinders: one oxygen, one acetylene, and one argon. The oxygen and acetylene gas are for the gas-welding and cutting torches. The argon gas is used in conjunction with the sigmette unit for inert-gas aluminum welding.

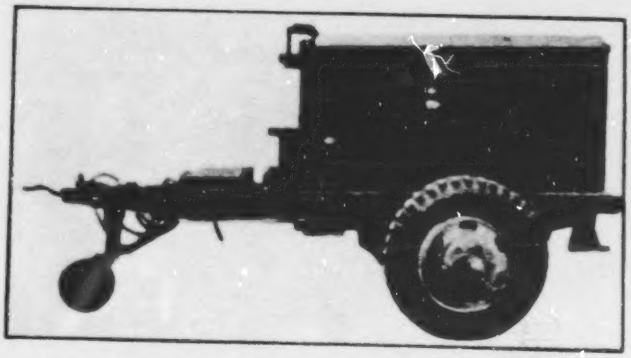


Fig 2-25. Arc-welding set, model LM-62.

(a) Theory of operation. The engine is a GM Detroit diesel model 2913 2-cycle, water-cooled engine. It is directly coupled to the dc generator. The welding generator, with its attached exciter, converts mechanical energy to electrical energy. The exciter is a heavy-duty, self-excited, shunt-wound dc generator which provides a nominal 115-volt dc excitation voltage for the welding generator. The exciter also provides 115-volt dc power to operate small handtools and lights connected to the utility outlets on the control panel; however, if the voltage required is critical, the output voltage should be measured at the utility outlet and the engine speed should be set at the desired voltage. The voltage range provided with the operating range of the engine can damage many small electrical tools or accessories. The exciter is rated at 5 kw (kilowatts). The power for the main generator field is controlled by the job selector (voltage control) rheostat. The voltage control rheostat and the polarity switch determine the polarity and voltage level of the fixed field of the main generator. The main generator has three fields. The first is excited at a fixed level from the exiter as described above. The second is a series field which is excited by the welding current so that the more current drawn by the arc, the higher will be the excitation in order to sustain the current at the desired level. The third field is a shunt field which bucks or tends to cancel the effort of the series or second field. The current in the shunt field is controlled by the setting of the current-control reactor. With the current control set for maximum current output, the shunt field would receive very little current to buck the series field, and current output would be maximum. If the current control is set for minimum output, the shunt field receives maximum current, canceling the effect of the series field and reducing the current output to minimum. The generator is rated 300 amperes at 40 volts with a duty cycle of 60 cps (cycles per second), and the current range is from 60 to 375 amperes.

(b) Controls and instruments. This subparagraph describes, locates, and illustrates the various controls and instruments of the welding set.

1. Engine controls (fig 2-26). The engine control panel is located in the aft section of the instrument panel. The controls and instruments required for the proper operation of the engine are described below.

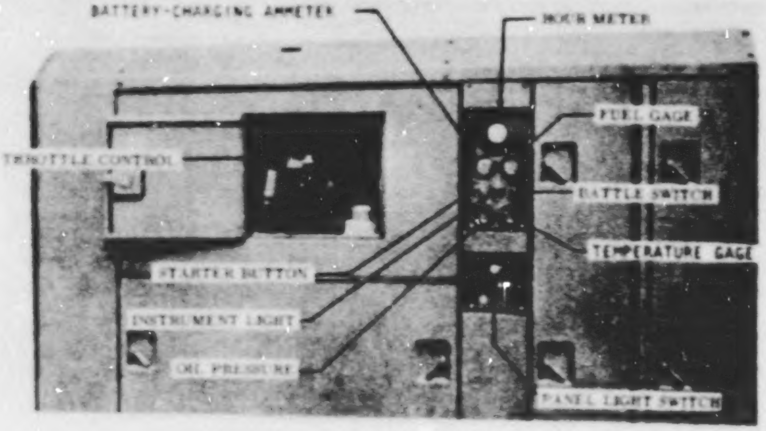


Fig 2-26. Engine controls.

a. Hour meter. Located at the top center of the engine instrument panel. It indicates total hours of engine operation.

b. Fuel gage. Located at the top right of the instrument panel. It indicates the quality of diesel fuel remaining in the tank.

c. Battle switch. Located at the center right of the instrument panel. This switch disconnects all safety circuits to the engine.

d. Water temperature gage. Located at the bottom right of the instrument panel. It indicates the engine coolant temperature.

e. Oil-pressure gage. Located at the bottom left of the panel. It indicates engine lubricating oil pressure.

f. Starter button. Located at the center left of the engine control panel. It energizes the starting motor to crank the engine.

g. Battery-charging ammeter. This indicator is located at the top left of the engine control panel. It indicates the charging or discharging rate of the battery.

h. Panel light switch. Located on a separate panel directly below the engine control panel. It turns on panel lights to illuminate controls and instruments.

2. Welding generator controls and instruments (fig 2-27). The welding generator controls and instruments are located on the forward section of the control panel. The controls for the proper operation of the welding generator are described below

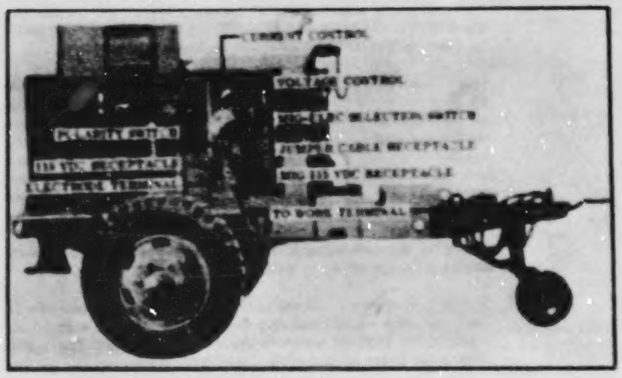


Fig 2-27. Welding generator controls and instruments.

a. Current control. The current control is located at the top of the generator panel. Its purpose is to vary the current output of the welding generator.

b. Voltage control (job sector). Located at the top center of the generator control panel, the voltage control varies the exciter voltage of the welding generator.

c. Polarity switch. Located in the center of the generator control panel, this switch controls the polarity of the electrode. Electrode polarity may be switched from positive to negative as required.

d. Utility outlets. Located at the bottom left of the generator control panel, the utility outlets supply voltage for small tools and accessories.

e. Sigmette outlets. Located at the bottom left of the generator control panel. The sigmette outlets permit the welding of aluminum or small-gage metal.

f. Welding selector switch. Located in the center of the generator control panel, this switch permits the selection of the output terminals of the welding generator or sigmette outlet.

g. Welding generator terminals. The welding terminals are located on the bottom of the generator panel. The electrode holder and work cables are attached here to obtain welding current.

(c) Operation. Prior to operation of the model LM-62 welding set, or any equipment for that matter, a complete inspection of the unit must be made to insure safe and continuous operation. Most of this is by the "eyeball" method. The following services must be performed prior to operation.

1. Remove the radiator cap and fill the radiator and cooling system with fresh clean water. If freezing weather is anticipated, the system must be protected. Add sufficient antifreeze to lower the freezing point of the coolant to the lowest expected temperature. Remove the oil filler cap and fill crankcase to the full mark on the dipstick with the appropriate quality and grade of lubricating oil. Remove and disassemble the air cleaner. Make sure it is clean and fill the oil cup to the level indicated, using the same grade of oil as used in the crankcase. Remove the fuel tank cap and fill the tank with diesel oil conforming to Federal Specification VV-F-800. Replace fuel cap securely. Fill the batteries with the electrolyte provided. The correct level of the electrolyte is

3/8 to 1/2 inch above the plates. Do not overfill. If the batteries contain electrolyte, check the level and add distilled water to the required level. After these initial steps have been completed, a complete inspection of the entire welding set should be made to insure that all components are securely mounted and all connections are tight. Check the following prior to operating and when securing equipment engine electrical system; engine controls and indicators; generator and exciter controls; terminals, leads, commutators, and brushes; engine head, block, and accessories; trailer, paying particular attention to tires and wheels; on-equipment tools and equipment; and accessory equipment. Report any damage or missing equipment to the proper authority. Now the welding machine is ready to be operated, but there is still a consideration prior to the actual operation, for example, the operating site. The following recommendations and precautions should be considered in selecting a site.

2. Indoor installation. When indoor welding operations are required, make sure that adequate ventilation is provided. A flexible metal hose should be used to conduct the exhaust gases to the outside. Locate the welder so that the exhaust line is as short as possible. Avoid locations having water-soaked floors.

3. Outdoor installation. When the welder is to be operated outdoors, see that the location is on firm ground and that some protection is provided from inclement weather. When the welder must be left outdoors overnight, cover it entirely with a tarpaulin securely lashed in place. Position the welder as close to the work as possible so that short cables can be used. The welder can be operated in inclement weather without any special protection, but take advantage of any natural protection that exists. If an appreciable wind is blowing, face the engine radiator to the wind, and chock the wheels.

4. Operating under normal conditions. Now that the machine is set up to weld, start the engine and warm up the welder. Follow the next eight steps to start the welding machine.

   1st. Place manual lever on the governor in the IDLE detent.

   2d. Turn the battle switch to ON. This electrically activates the engine meters.

   3d. Depress the starter botton and crank engine until it starts. Do not use the starter motor for more than 30 seconds at a time without allowing 2 minutes for the motor to cool between starts.

   4th. Open the radiator shutter doors.

   5th. After the engine has run for approximately 10 to 20 seconds, check the oil-pressure gage. If it shows no oil pressure at the end of 30 seconds, stop the engine by placing the manual lever on the governor in the STOP position. Locate the source of trouble before restarting the engine.

   6th. Check all instrument gages to determine if they are functioning correctly. If there is any indication from any gage that a component system is not operating correctly, shut down the machine and find out why. Check for any oil, water, or fuel leaks.

   7th. Observe engine operation for smoothness, quietness, and exhaust condition.

   8th. Before starting to weld, advance the manual lever on the governor to RUN.

Selection of the proper voltage and current depends on the size of the electrode, the thickness and position of the stock being welded, and the skill and experience of the welder. Selection of the proper electode and welding process depends on the type of metal being welded. Figures 2-28 and 2-29 give welding information for various base metals and alloys.

Electrode diameter (in.)	Amperes minimum	maximum	Length (in.)
1/16	40	60	11-1/2
3/32	70	90	14 or 18
1/8	110	135	14 or 18
5/32	150	180	14 or 18
3/15	180	220	14 or 18
1/4	250	300	14 or 18
5/16	300	425	14 or 18
3/8	450	550	14 or 18

Fig 2-28. Current-setting range for bare and lightly coated electrodes.

Electrode used	Mineral coated		Cellulose coated	
Size-diameter (in.)	Flat position (amperes)	Vertical and overhead positions (amperes)	Flat position (amperes)	Vertical and overhead positions (amperes)
3/32	60	60		
1/8	120	110	130	110
5/32	150	140	160	140
3/16	175	160	200	160
1/4	250	---	300	
5/16	325	---	400	
3/8	425	---	500	

Fig 2-29. Current setting used with mineral and cellulose coated electrodes.

The best way for an operator to become familiar with the operation of the interacting controls is to weld sample beads on various scraps of metals with different combinations of control settings and different electrodes. Start the engine and let it warm up. Turn the polarity-reversing switch to OFF. With the handle in this position, the exciter is disconnected from the welding generator and there is no output from the welding generator. Connect welding cables to output terminals and the ground clamp to a piece of scrap metal of a type listed in figure 2-30. Obtain the type of material of electrode shown in figure 2-30. Obtain the type and material of electrode shown in figure 2-30 opposite the type of metal selected, and place it in the electrode-holder. Turn the voltage control to the center of the sector marked Normal Welding Range. The voltage control is divided into four colored sections. The yellow section marked Large Electrodes gives a high open-circuit voltage and is used chiefly for large electrodes. The black section marked Normal Welding Range gives a medium-high open-circuit voltage and is generally used on positioned work for some of the larger size electrodes or where poor fitting exists on overhead or verticle welding. The red section marked Overhead and Vertical provides a medium-low open-circuit voltage to give sufficient punch to the arc to force the metal across the arc gap and give greater penetration. This setting may also be used for some of the smaller size electrodes. The section marked Special Applications provides a still lower open-circuit voltage and is used for special jobs requiring the smallest size electrodes and very low current values. At the present time, the Marine Corps is modifying all model LM-62's with a 75-ohm resistor for low amperage control for welding thin-skin metals, such as aluminum alloys. Set the current control to the setting obtained from figure 2-28 or 2-29 and based on the type and size of electrode. The current control is calibrated directly in amperes. The plate on this control has three arrows--yellow, black, and red---which correspond to the three colored sections of the voltage control. When the voltage control is set in the yellow section of the dial, the approximate welding current will be indicated by the yellow arrow of the current control. The same is true of the black and red arrows of the current control when the voltage control is set on those sections of the voltage control dial.

When the engine coolant temperature has reached the operating range, turn the polarity switch to the position recommended in figure 2-30 for the type of metal being welded. Use electrodes negative position for straight polarity, and electrode positive position for reverse polarity. Weld a sample bead, break the arc, then turn the voltage control to the center of Overhead and Vertical position. Notice the difference in the bead. Use different current settings, different metals, and different electrodes. In that way you can improve your skill and also gain welding experience.

Base metal or alloy	Welding process a/	Polarity b/ material	Welding electrode	Type deg F	Preheating
ALUMINUM AND ALUMINUM ALLOYS					
1. Pure aluminum (25)	MAW	Reverse	Pure aluminum or 95% aluminum 5% silicon	Shielded-arc	500 to 800
	CAW	Straight	Pure aluminum or 95% aluminum 5% silicon	Flux-coated	500 to 800
2. Aluminum alloys (general)	MAW	Reverse	95% aluminum 5% silicon	Shielded-arc	500 to 800
	CAW	Straight	95% aluminum 5% silicon	Flux-coated	
3. Aluminum manganese alloy (3s)	MAW	Reverse	95% aluminum 5% silicon	Shielded-arc	500 to 800
	CAW	Straight	95% aluminum 5% silicon	Flux-coated	500 to 800
4. Aluminum-magnesium-chromium alloy (52s)	MAW	Reverse	95% aluminum 5% silicon	Shielded-arc	500 to 800
	CAW	Straight	95% aluminum 5% silicon	Flux-coated	500 to 800
5. Aluminum-magnesium-manganese alloy (4s)	MAW	Reverse	95% aluminum 5% silicon	Shielded-arc	500 to 800
	CAW	Straight	95% aluminum 5% silicon	Flux-coated	500 to 800
6. Aluminum-silicon-magnesium alloys (51S) (53S)	MAW	Reverse	95% aluminum 5% silicon	Shielded-arc	Up to 400
	CAW	Straight	95% aluminum 5% silicon	Flux-coated	Up to 400
7. Aluminum-copper mangnese alloys Duraluminum (17S) (24S)			Arc welding not recommended.		
8. Aluminum clad			Arc welding not recommended.		

Fig 2-30. Welding process and electrode selection for various base metals and alloys.

Base metal or alloy	Welding process [a]	Polarity [b] material	Welding electrode	Type deg F	Preheating
CARBON STEELS					
1. Low-carbon (up to 0.30% C)	MAW	Straight	Mild steel	Bare or light-coated	Up to 300
	MAW	Reverse	Mild steel	Shielded-arc	Up to 300
	CAW	Straight	Mild steel	Use a flux	Up to 300
	MAB	Reverse	Bronze	Shielded-arc	Up to 300
2. Medium-carbon (0.30% to 0.50% C)	MAW	Reverse	25-20 or modified 18-8 stainless steel	Shielded-arc	300 to 500
	MAW	Reverse	Mild steel or high-strength	Shielded-arc	300 to 500
3. High-carbon	MAW	Reverse	25-20 or modified 18-8 stainless steel	Shielded-arc	500 to 800 Stress-relieve by heating 1,200 to 1,450 for 1 hour per inch of thickness and cool slowly.
	MAW	Reverse	Mild steel or high-strength	Shielded-arc	500 to 800
4. Tool steel (0.80% to 1.5% C)	MAW	Reverse	25-20 or modified 18-8 stainless steel	Shielded-arc	Up to 800
	MAW	Reverse	Mild steel or high-strength	Shielded-arc	Up to 1,000

[a] Welding process:
CAB - carbon-arc brazing
CAW - carbon-arc welding
MAB - metal-arc brazing
MAW - metal-arc welding

[b] Straight polarity - electrode negative; reverse polarity - electrode positive.

Fig 2-30. Welding process and electrode selection for various base metals and alloys--continued.

Base metal or alloy	Welding process	Polarity	Welding electrode material	Type	Preheating deg F
CAST IRONS					
1. Gray cast iron, machinable welds	MAW	Reverse	Monel, 18-8 stainless steel or mild steel	Shielded-arc	700 to 800
2. Gray cast iron, nonmachinable welds	MAW	Straight	Cast iron	Shielded-arc	700 to 800
	MAB	Reverse	Bronze	Shielded-arc	Up to 500
	CAB	Straight	Bronze	Shielded-arc	Up to 500
3. Malleable iron, machinable	MAW	Reverse	Monel 18-8 stainless steel or mild steel	Shielded-arc	700 to 800 Anneal-weld
4. Malleable iron, nonmachinable welds	MAW	Straight	Cast iron	Shielded-arc	700 to 800
	MAB	Reverse	Bronze	Shielded-arc	Up to 500
	CAB	Straight	Bronze	Shielded-arc	Up to 500
5. Alloy cast iron			Same as gray cast iron		
CAST STEELS					
1. Plain carbon (up to 25% C)	MAW	Reverse	Mild steel	Shielded-arc	200
	MAB	Reverse	Bronze	Shielded-arc	200
2. High manganese (12% Min)	MAW	Reverse	Weld with 25-20 stainless steel and surface with nickel manganese	Shielded-arc	no
3. Other alloys	MAW	Reverse	Mild steel	Shielded-arc	
COPPER AND COPPER ALLOYS					
1. Deoxidized copper	MAW	Reverse	Deoxidized copper, phosphor bronze, or silicon copper	Shielded-arc	500 to 800
	CAW	Straight	Deoxidized copper, phosphor bronze, or silicon copper	Shielded-arc	500 to 800
2. Commercial bronze and low brass	MAW	Reverse	Phosphor bronze or silicon copper	Shielded-arc	200 to 300

Fig 2-30. Welding process and electrode selection for various base metals and alloys--continued.

Base metal or alloy	Welding process	Polarity	Welding electrode material	Type	Preheating deg F
CAST STEELS--contd					
	CAW	Straight	Phosphor bronze or silicon copper	Use a flux	200 to 300
3. Spring, admiralty, and yellow brass	CAW	Straight	Phosphor bronze	Use flux	200 to 300
4. Muntz metal, Tobin bronze, naval manganese bronze	CAW	Straight	Phosphor bronze	Use a flux	300 to 300
5. Nickel	MAW	Reverse	High nickel alloy, phosphor bronze, or silicon copper	Shielded-arc	300 to 500
6. Phosphor bronze	MAW	Reverse	Phosphor bronze	Shielded-arc	200 to 300
	CAW	Straight	Phosphor bronze	Use a flux	200 to 300
7. Aluminum bronze	MAW	Reverse	Aluminum bronze or phosphor	Shielded-arc	200 to 300
	CAW	Straight	Aluminum bronze or phosphor bronze	Use a flux (optional)	200 to 300
8. Beryllium copper	CAW	Straight	Beryllium copper	Use a flux (optional)	500 to 800
IRON					
1. Wrought iron	MAW	Reverse	Mild steel	Shielded-arc	No
	CAW	Straight	Mild steel	Use a flux	No
	MAB	Reverse	Bronze	Shielded-arc	No
2. Low-carbon iron	MAW	Reverse	Mild steel	Shielded-arc	No
LOW-ALLOY HIGH-TENSILE STEELS					
1. General	MAW	Reverse	Same as base metal or high-strength or mild steel, or 25-20 stainless steel	Shielded-arc	Yes
2. Nickel alloy steel (3-3.5% Ni) (Up to 0.25% C) (More than 0.25% C)	MAW	Reverse	Nickel alloy or 25-20 stainless steel	Shielded-arc	No Slow cool
	MAW	Reverse	Nickel alloy or 25-20 stainless steel	Shielded-arc	300 to 600

Fig 2-30. Welding process and electrode selection for various base metals and alloys--continued.

Base metal or alloy	Welding process	Polarity	Welding electrode material	Type	Preheating deg F
IRON--contd					
3. Nickel copper steels	MAW	Reverse	Nickel alloy or 25-20 stainless steel	Shielded-arc	250 to 300
4. Manganese molybdenum alloy steels	MAW	Reverse	Carbon molybdenum or special electrode	Shielded-arc	250 to 300
5. Carbon molybdenum alloy steels (0.10% C to 0.20% C)	MAW	Straight or Reverse	Carbon molybdenum	Shielded-arc	300 to 400
(0.20% to 0.30% C)	MAW	Straight or Reverse	Carbon molybdenum	Shielded-arc	400 to 500
6. Nickel chromium alloy steels (1%-3.5% Ni) (Up to 0.20% C)	MAW	Reverse	Same as base steel or 25-20 stainless steel	Shielded-arc	200 to 300
(0.20% to 0.55% C)	MAW	Reverse	Same as base metal or 25-20 stainless steel	Shielded-arc	600 to 800
(High alloy content)	MAW	Reverse	Same as base metal or 25-20 stainless steel	Shielded-arc	900 to 1,000 Slow cool
7. Chrome-molybdenum alloy steels	MAW	Straight or Reverse	Chrome-molybdenum or carbon molybdenum	Shielded-arc	300 to 800 Slow cool
	CAW	Straight	Same as base metal	Use a flux	300 to 800 Slow cool
8. Chromium alloy	MAW	Reverse	Same as base metal or 25-20 stainless steel or 18-8	Shielded-arc	300 to 800
9. Chromium vanadium alloy steels	MAW	Reverse	Chrome molybdenum or carbon molybdenum	Shielded-arc	200 to 800
10. Manganese alloy steels (1.6% 1.9% Mn)	MAW	Reverse	Carbon molybdenum or mild steel	Shielded-arc	300 to 800
NICKEL AND NICKEL ALLOYS					
1. Nickel	MAW	Reverse	Nickel	Shielded-arc	200 to 300
	CAW	Straight	Nickel	Lightly flux-coated	200 to 300
2. Monel (67% Ni-29% Cu)	MAW	Reverse	Monel	Shielded-arc	200 to 300
	CAW	Straight	Monel	Lightly flux-coated	200 to 200

Fig 2-30. Welding process and electrode selection for various base metals and alloys--continued.

Base metal or alloy	Welding process	Polarity	Welding electrode material	Type	Preheating deg F
NICKEL AND NICKEL ALLOYS--contd					
3. Incone (79% Ni-13% CR-6% Fe)	MAW	Reverse	Same as base metal	Shielded-arc	200 to 300
STAINLESS STEELS					
1. Chromium alloys (12% - 28% Cr)	MAW	Reverse	25-20 or columbium-bearing 18-8 stainless	Shielded-arc	No
2. Chromium-nickel alloys	MAW	Reverse	25-20 or columbium-bearing stainless	Shielded-arc	No

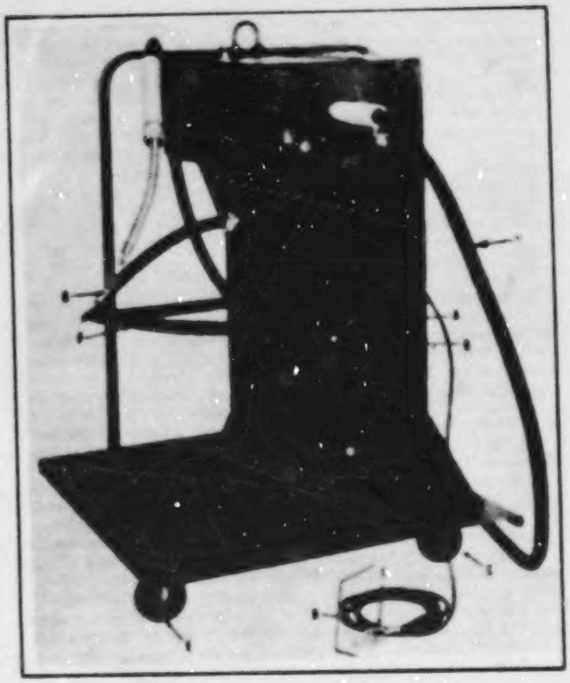
Fig 2-30. Welding process and electrode selection for various base metals and alloys--continued.

(d) Accessories. The welding set, model LM-62, also contains provisions for gas welding and hard surfacing of metals, as well as aluminum welding by the inert-gas method. Each of these methods will be discussed later in the chapter.

1. Gas welding. Storage space for the gas-welding regulators, hoses, and other equipment is provided in the accessory box compartment. Gas cylinders are mounted on the trailer forward of the welding generator enclosure. A tube is situated next to the cylinder on the left side of the trailer for storage of long welding rods.

2. Sigmette unit. The inert-gas aluminum welding unit is stored in the accessory compartment and secured in place on the shelf by a strap. A receptacle is provided on the generator panel for connecting and operating the sigmette unit.

1. Hard-surfacing welding machine (fig 2-31). A model HSM-62 hard-surfacing machine, manufactured by Libby Welding Co., may be mounted on a bracket on the forward end of the trailer. This unit is a separate item and is not provided for on the machine. All units do not rate this machine. It is used to apply extremely hard alloys to the surface of a softer metal to increase its resistance to wear, abrasion, corrosion, or impact.



Key	Item	Key	Item
A	Dial	E	Caster
B	Handwheel	F	Clamp
C	Caster	G	Lead
D	Lead	H	Cable assembly
D1	Clip		

Fig 2-31. Welding machine, hard-surfacing.

(e) Organizational maintenance. This is defined as maintenance that is limited inspection, lubrication, and preventive maintenance. Organizational maintenance personnel, assisted by the operator, must perform the preventive maintenance services regularly to be sure that the welder functions properly and to reduce the chances of mechanical failure. Inspections by the operator must be made before, during, and after operation of the welder. Inspections of assemblies and subassemblies must include any supporting members and connections, and must determine whether the unit is in good condition, correctly assembled, secure, or excessively worn. The inspection for good condition is usually a visual external inspection to determine whether the welder is damaged beyond the safe or serviceable limits, or to determine if it is in such a condition that damage will occur to the machine should it be operated. Before-operation services will be performed to determine if the condition of the equipment has changed since it was last operated, and to make sure the equipment is ready for operation. Any deficiencies must be corrected or reported to the proper authority before the welder is put into operation. Locate the welder as close to the work as possible, with brakes set. Be sure the ground is firm. If operating indoors, ventilate exhaust gases to the outside air and provide adequate ventilation. Check the fuel supply and fill the tanks if necessary. Check the oil level in the crankcase and the coolant in the radiator. If antifreeze is used, allow for expansion. Check for leads, paying particular attention to the lubricating and cooling systems. Make a visual inspection of the unit for missing components and loose bolts, nuts, screws, wiring, etc.; replace any that are found missing. When starting the welder, see that no tools, rags, or other materials are left on top of the engine. During operation of the welder, the operator is responsible for correcting or reporting any deficiencies, malfunctions, or abnormal conditions of the welder; also for checking the instruments and gages. At normal operating speed and temperature, the no-load readings of the gages should be:

Engine oil pressure	20-35 psi
Battery-charging ammeter.	Slight charge
Coolant temperature	160°-180°F

If the engine oil pressure shows an unusual drop, stop the engine immediately and check the unit and lubricating system for cause. Correct the trouble before restarting the engine. The same procedure should be followed if the engine cooling system boils over or the temperature rises above normal. The operator must also be alert for unusual or faulty operation, such as failure of engine to return to idle speed when welding arc is broken, or for excessive smoking or vibration. Check the welder thoroughly and either correct the fault or stop the engine and report it to the proper authority. With only brief experience, the operator will become accustomed to the usual sounds of engine operation and will become familiar when strange noises occur that are not characteristic of a normal operating engine. When noises other than normal occur, stop the engine and determine the cause and correct it before restarting. During halts (engine shutdown) even those of short duration, it is the responsibility of the operator to thoroughly inspect the welder and correct any deficiency noted. The unit must be lubricated at specified intervals to minimize wear and prevent damage and breakdowns. Use the correct lubricants and do not overlubricate. Wipe off all excess and spilled lubricants after application. Follow the lubrication chart appropriate to the welder. When performing organizational maintenance, do not attempt repairs that you are not familiar with, are not in your area of responsibility, or are not classified as organizational maintenance. These are the duties of experienced personnel and higher echelons of maintenance. Organizational maintenance is performed by maintenance personnel assisted by the operator at weekly and monthly intervals. The weekly interval will be equivalent to 60 hours of use. The monthly interval will be equivalent to 4 weeks or 240 hours of use, whichever occurs first. The preventive maintenance services to be performed at these regular intervals are listed in table 2-1.

Table 2-1. Organizational Maintenance of Model LM-62 Trailer-Mounted Arc-Welding Set.

Intervals			Procedure
Technical inspection	Monthly (4 weeks or 240 hr of use)	Weekly (60 hr of use)	
X	X	X	Before operation services. Check and perform services listed previously in paragraph 4-2a (1) (c).
X	X	X	Lubrication. Inspect entire unit for missing or damaged lubricating fittings and for indication of insufficient lubrication.
--	X	X	Fittings. Replace missing or damaged fittings. Lubricate as specified in lubrication guide.
X	X	X	Tools and equipment. Inspect condition of all tools and equipment assigned to the welder. Check condition and mounting of toolbox.

Table 2-1. Organizational Maintenance of Model LM-62 Trailer-Mounted Arc-Welding Set.

Intervals			Procedure
Technical inspection	Monthly (4 weeks or 240 hr of use)	Weekly (60 hr of use)	
X	X	X	See that all tools and equipment assigned to the welder are clean, serviceable, and properly stowed or mounted. See that the toolbox is in good condition and that the lid closes and fastens properly.
X	X	X	Appearance. Inspect general appearance of unit, paying particular attention to cleaness, legibility of identification markings, and condition of paint.
--	X	X	Correct of report any deficiencies noted.
			ENGINE AND ACCESSORIES
X	X	X	Cylinder head, manifold, and gaskets. Inspect cylinder head, manifold and exhaust pipe for leaks, loose or missing bolts, and defective gaskets.
--	X	X	Tighten or replace any loose or missing manifold and exhaust pipe mounting bolts, nuts, and lockwashers. Replace any defective gaskets. On new or reconditioned engines, check all cylinder head bolts for tightness at the first weekly service. (The correct torque wrench pull is 75 foot-pounds for cylinder head bolt.)
X	X	X	Oil filters. Inspect oil filter assembly and connections for leaks while engine is running.
--	X	X	Service oil filter as specified in the lubrication guide. After servicing, check carefully for leaks while engine is running.
X	X	X	Radiator. Inspect radiator for leaks, for obstructions in core air passages, and for loose mounting bolts. Check all cooling-system hoses for leaks, excessive deterioration, and loose connections. Check operating temperature and condition of coolant. If coolant temperature remains below 140°F, or rises above 190°F during operation, thermostats may be defective. If antifreeze is used, check its freezing point.
--	X	X	Drain, flush, and refill cooling system if coolant is contaminated with rust or dirt. See that core air passages are clean. Replace any damage or defective cooling-system hoses, lines, and gaskets. See that all mounting bolts and connections are tight. Protect coolant from freezing, and record its freezing point on NAVMC 10560.
X	X	X	Water, pump, fan, and shroud. Inspect water pump for leaks and for loose or missing mounting and assembly screws. Check the condition and mounting of fan blades and shroud.
--	X	X	Tighten or replace loose or missing bolts and screws. If pump leaks, replace it with a new or reconditioned pump.
X	X	X	Belts and pulleys. Inspect for excessively worn, cracked, or frayed belts. Check belt tension and condition and alinement of pulleys. (Belts are properly adjusted when they can be deflected 1 inch from normal position at a point midway between the pulleys.)

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Table 2-1. Organizational Maintenance of Model LM-62 Trailer-Mounted Arc-Welding Set.

Intervals			
Technical inspection	Monthly (4 weeks or 240 hr of use)	Weekly (60 hr of use)	Procedure
--	X	X	Adjust the tension of the belts if necessary. Replace belts if frayed or badly worn. Replace all belts in sets. Never install new belts with worn pulleys, or new pulleys with worn or frayed belts.
X	X	X	Governor. Inspect for loose or missing mounting bolts. Check for proper operation and adjustment.
			FUEL SYSTEM
X	X	X	Fuel tank, cap, and gasket. Check condition and mounting of fuel tank. Inspect fuel tank lines and connections for leaks, kinks, and obstructions. Check fuel tank cap and gasket for wear and damage.
X	X	X	Tighten or replace loose or missing mounting bolts. See that the air vent is open, and filler cap clean and tightfitting. Replace fuel tank cap and gasket if necessary. Repair or replace leaky or damaged fuel lines.
			ELECTRICAL SYSTEM
X	X	X	Battery. Inspect battery cases for cracks, leaks, loose mounting bolts and clamps, or for dirt and corrosion on top of case. Check for loose cable connections and corroded or damaged terminals and cables. Check level of electrolyte (it should be about 3/8 inch above the plates). Check electrolyte with a hydrometer and record readings on NAVMC 10560. (Readings from 1.275 to 1.300 indicate a fully charged battery; readings between 1.200 and 1.215 indicate a battery more than half discharged.
--	X	X	Clean all dirt, mud, and corrosion from top of batteries, posts, clamps, cables, and cable terminals. Replace damaged cables. Apply a thin film of chassis grease over the terminals after they are clamped tight. Add clean water, if needed, but do not overfill. If freezing temperatures prevail, the batteries must be charged long enough to mix the solution thoroughly. See that the batteries are securely mounted and that the caps are tight and the ventholes open.
X	X	X	Generator and starter. Inspect both for loose mounting bolts and damaged or loose external wiring connections.
--	X	X	Inspect commutators and brushes for excessive wear, dirt, and oil deposits. See that brushes are free in their holders and that they make contact with the commutators.
--	X	X	See that starter and generator are securely and properly mounted. See that brush wire connections are tight and that brushes are free in the holders and make good contact with the commutators.
X	X	X	Voltage regulator. Check operation of voltage regulator. (After the starter is used, the ammeter should show an appreciable rate of charge. After the battery is fully charged the ammeter should show no charge or only a slight charge.)

Table 2-1. Organizational Maintenance of Model LM-62 Trailer-Mounted Arc-Welding Set.

Intervals			Procedure
Technical inspection	Monthly (4 weeks or 240 hr of use)	Weekly (60 hr of use)	
--	X	X	See that the regulator is securely mounted. Tighten or replace loose or missing mounting and regulator cover screws.
			CONTROL SYSTEM
X	X	X	Gages (meters). Inspect operation of all gages and meters. See that all gages are mounted securely and that all connections are tight and clean. Under normal operating conditions the gages and meters should read as follows: Oil pressure, 26 psi; battery-charging ammeter, in charging range (pointer should be on charge side of dial when engine is running); water temperature gage, normally 180°. (Many run slightly more or less depending on climatic conditions; check for extremes.)
--	X	X	Tighten loose connections. Replaced damage or defective gages.
			FRAME
X	X	X	Frame. Inspect for cracked, broken, or splitting welds, and loose or missing bolts, nuts, washers, and bent or displaced members.
--	X	X	Tighten or replace all loose or missing bolts, nuts, and washers. Repair or report to proper authority all bends, cracks, and breaks.
			GENERATORS
X	X	X	Commutator and brushes. Inspect commutator, brush holders, and brushes for cracks, abrasion, wear, and oil deposits. Check for excessive sparking. See that brushes move freely in their holders and that springs provide sufficient pressure. (The correct spring pressure is 2 lbs.)
--	X	X	Clean commutator if necessary. If available, use clean, dry compressed air to clean the dust and dirt from around the fields, rotor, air ducts, commutator, and brushes.
X	X	X	Wiring. Inspect generator wiring for worn, cut, cracked, swollen, or frayed insulation. Check wiring for loose and corroded connections.
--	X	X	Correct or report to proper authority any deficiencies noted.
X	X	X	Control panel. See that all meters, gages, and switches function properly, and that the entire control panel is clean and securely mounted. See that all terminal connections on back of the panel are clean, free from rust and corrosion, and securely tightened.
--	X	X	Correct or report to proper authority and deficiencies noted.

Dynamotor-welder (fig 2-32). The dynamotor-welder is a component of the general purpose repair trailer set No. 1 and the organizational repair set No. 2. The difference between the two is that the No. 1 set is driven by an engine mounted in the trailer and the No. 2 set is driven by the truck engine. Herein we will refer to the trailer-mounted welder, whose operation is the same for both models. A dynamotor-welder is installed in the trailer and driven by the shop engine through a manually operated clutch or by external power source. When the welder is driven by the engine, it provides direct current for welding and alternating current for the shop set tools and equipment. When the welder is driven by an external power source, the ac generator acts as a synchronous motor and drives the welder to provide direct current for welding. The external power is also used to operate the shop set tools and tools and equipment. The normal power, either input or output, is 220-volt, 3-phase, 60-cycle, alternating current.

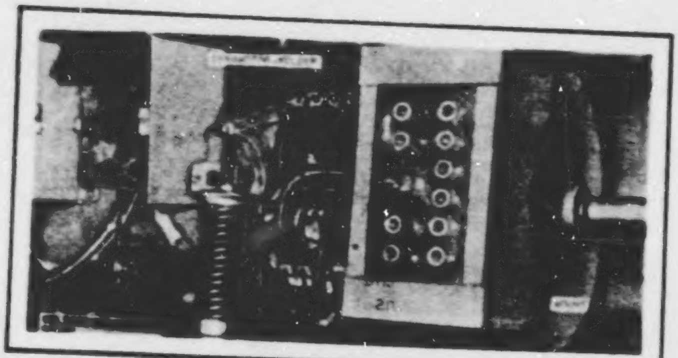


Fig 2-32. Dynamotor-welder.

(a) Starting and stopping the dynamotor-welder. The shop set is equipped with an engine to power the welder and air compressor. The frequency, 50 or 60 cycles determines the running speed, 1,500 or 1,800 rpm, respectively, of the engine. The dynamotor-welder frequency is dictated by the frequency required at the remote utilization and the frequency switch, located on the welder control instrument panel (fig 2-34). This is usually set at 60 cps, although the contents of the shop set will operate satisfactorily on either frequency. The speed adjustment and power engagement, as well as simple engine startup, become part of the overall engine starting procedure. As mentioned before, when the welder is powered internally by the engine, it generates both alternating and direct current; when it is powered by an outside source, it generates direct current only. In either case, use of ac or dc depends on the proper setting of the ac and dc electrical systems of the shop set. The dc is used for welding. The 3-phase ac generator is used to power external loads and various shop set components. The current to be used within the shop set, if generated at 380 or 440 volts, is reduced by a transformer to 220 volts, and in part, to 110 volts. If generated at 220 volts, the current again is reduced to 110 volts. Starting the two electrical systems is done at the control panel (fig 2-35). Start the engine and adjust speed to 1,800 or 1,500 rpm as necessary, referring to figure 2-35. The engine governor will maintain adjusted speed under various load conditions. Figure 2-33 illustrates the engine controls and instruments when the engine is running with the clutch in the disengaged position. After the shop engine has been started and has reached operating temperature, energize the ac and dc internally powered electrical systems, referring to figure 2-36 and the steps listed.

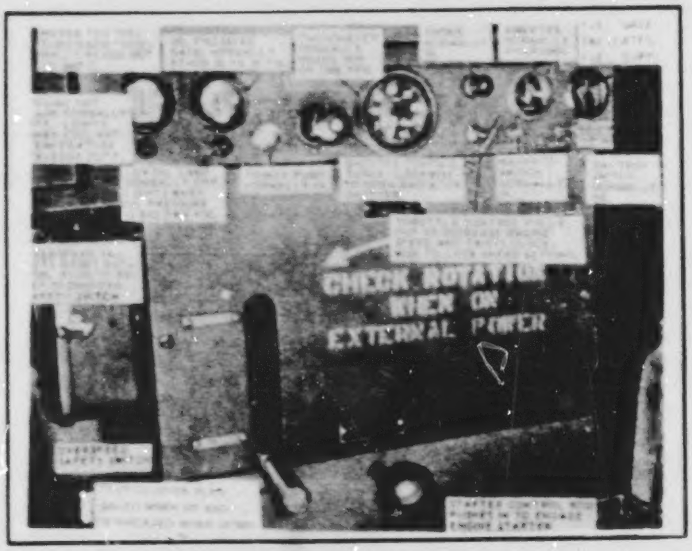

CHECK ROTATION
WHEN ON
EXTERNAL POWER

Fig 2-33. Engine controls and instruments.

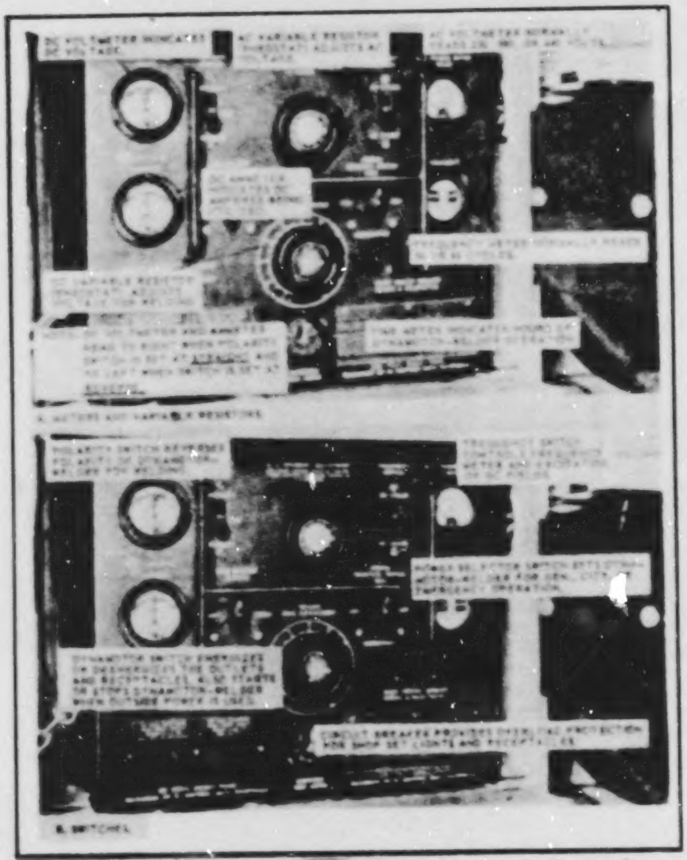

DC VOLTMETER INDICATES DC VOLTAGE
TIME METER INDICATES HOURS OF DYNAMOTOR-WELDER OPERATION
A. METERS AND VARIABLE RESISTORS
CIRCUIT BREAKER PROVIDES OVERLOAD PROTECTION FOR SHOP SET LIGHTS AND RECEPTACLES
B. SWITCHES

Fig 2-34. Dynamotor-welder controls and instruments.

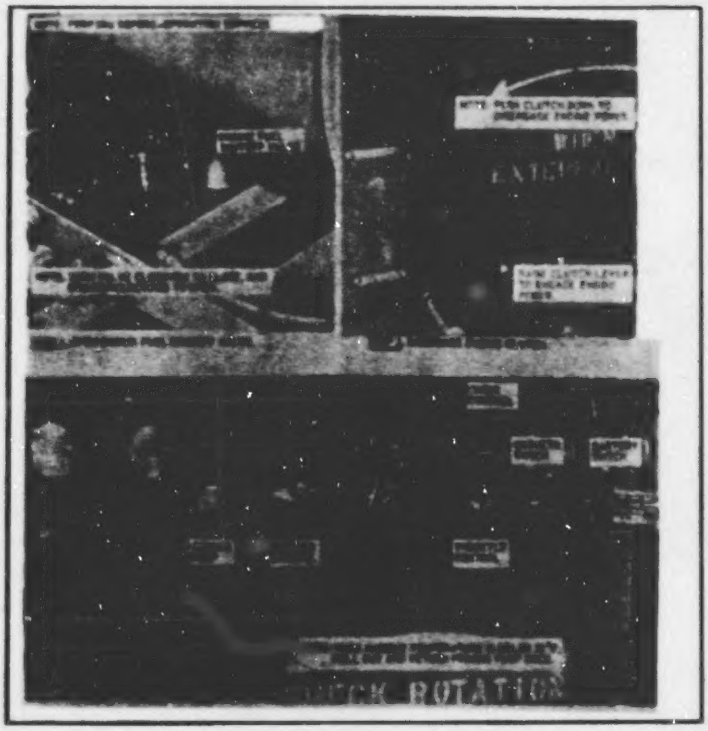


Fig 2-35. Starting shop set engine.

Step 3. Turn shutter control fully counterclockwise to CLOSE.
Step 4. Push magneto switch to START.
Step 5. Pull throttle control out 1 inch.
Step 6. Pull choke control out.
Step 7. Place battery switch on.

Step 8. Push starter control rod in to start engine.

Step 9. After engine starts, close choke gradually and adjust throttle control to give tachometer reading of 600 to 900 rpm.

Step 10. Open shutter control partially. Operate engine and adjust shutter control to stabilize engine temperature between 150°F and 180°F.

CAUTION: IF ENGINE FAILS TO START WITHIN 30 SECONDS, RELEASE STARTER CONTROL ROD. ALLOW STARTER TO COOL FOR 2 MINUTES BEFORE ATTEMPTING TO START ENGINE AGAIN.

Fig 2-35--continued

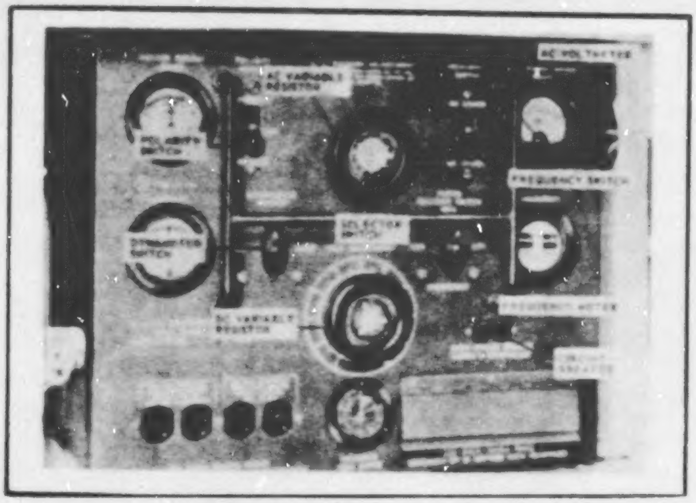

AC VOLTMETER
AC VARIABLE RESISTOR
POLARITY SWITCH
FREQUENCY SWITCH
SELECTOR SWITCH
DYNAMOTOR SWITCH
DC VARIABLE RESISTOR
FREQUENCY METER
CIRCUIT BREAKER

Fig 2-36. Starting and stopping ac-dc electrical systems with internal power.

Step 1. Set circuit breaker at ON and frequently switch at 50 or 60 cycles as necessary.

Step 2. Set polarity switch at OFF and dc variable resistor at zero.

Step 3. Set selector switch at GEN (generator).

Step 4. Engage engine (fig 2-35, step 2).

Step 5. Hold dynamotor switch momentarily on start.

Step 6. Regulate ac variable resistor to give desired reading on ac voltmeter.

Step 7. Adjust engine speed as necessary to give desired reading on frequency meter.

To use the dc electrical system only, perform steps 1 through 7 above and then set the selector switch to OFF, momentarily holding the dynamotor switch at the STOP position. To stop the engine and deenergize the electrical systems when they are internally powered, the following steps must be performed.

Step 1. Set the selector switch to OFF.
Step 2. Momentarily hold dynamotor switch at STOP.
Step 3. Disengage clutch by moving the clutch lever to the DOWN position.
Step 4. Unlock throttle and push in.
Step 5. Pull magneto switch out.
Step 6. Place battery switch at OFF.
Step 7. Close fuel shutoff valve.

To start the ac-dc systems with external power, connect the external power lead (fig 2-37) to the input/output receptacle. Referring to figure 2-38, follow the steps to energize the system.

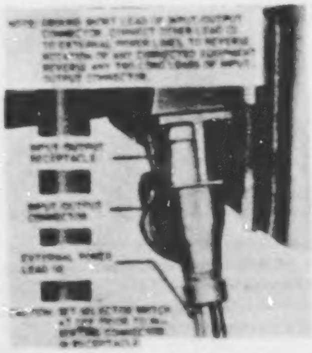
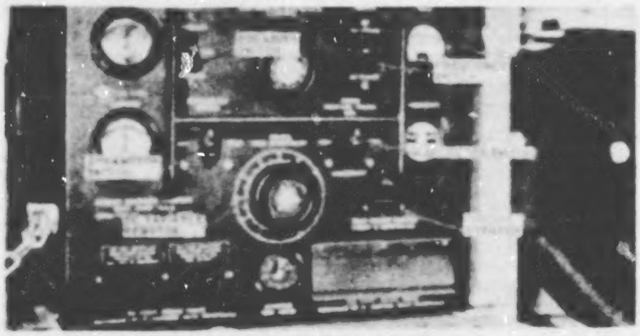

INPUT OUTPUT RECEPTACLE
INPUT OUTPUT CONNECTOR
EXTERNAL POWER LEAD

Fig 2-37. External power supply, removal and installation.

NOTE: TO UTILIZE DC ELECTRICAL SYSTEM ONLY PERFORM STEPS 1 THROUGH 4 BELOW, CHECK PER NOTE BELOW, AND FOLLOW BY SETTING SELECTOR SWITCH AT OFF POSITION.



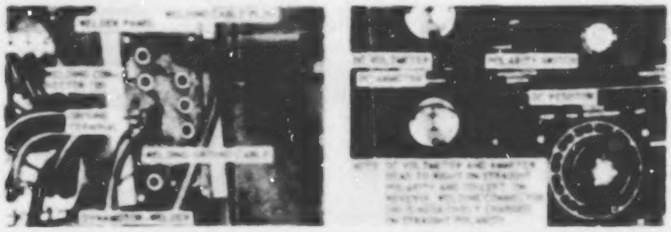
Note: Check direction of rotation of dynamotor-welder; it should be counter-clockwise viewed from non-drive end. If rotation is incorrect:

1. Stop dynamotor-welder and disconnect external power.
2. Reverse connection of any 2 incoming power leads at input/output connector.
3. Repeat steps 1 through 4 below.

Step 1. Set circuit breaker at ON and frequency switch at 50 or 60 cycles as necessary.
Step 2. Set polarity switch at OFF and dc resistor at zero.
Step 3. Set selector switch at CITY.
STEP 4. Hold dynamotor switch momentarily on start.

Fig 2-38. Starting ac-dc electrical systems with external power.

(a) Welder operation. To operate the welder, after the ac-dc systems have been energized, whether it be with an internal or external power source, refer to figure 2-39 and follow the steps listed.



Step 1. Be sure polarity is at OFF and dc variable resistor at zero, or set switch and resistor to these positions.

Step 2. Connect welding ground cable to ground terminal of welder panel.

Step 3. Connect ground cable to workpiece.

Step 4. Install welding cable plug in welding connector marked 1.

Step 5. set polarity switch at straight or reverse as necessary.

Note: Powered flux, carbon, and bare electrodes usually use straight polarity, putting 2/3 of welding heat in the workpiece, copper alloy and heavily coated electrodes generally use reverse polarity, putting 2/3 of welding heat in the electrode.

Step 6. Install electrode in electrode holder and weld, if more welding heat is required, turn dc resistor clockwise to increase welding current.

Note: Perform steps through 9 below only if still greater welding heat is required. If satisfactory welds are produced by performance of this step, (step 6) complete welding and perform step 10 below.

Step 7. Repeat step 1 above.

Step 8. Remove welding cable plug and install it in next higher numbered welding connector.

Step 9. Repeat steps 5 and 6 above and notes beneath as necessary.

Step 10. When welding is interrupted, set polarity switch at OFF. When welding is completed, set polarity switch at OFF, turn dc resistor fully counterclockwise, and stop the dynamotor-welder.

Fig 2-39. Operation of dynamotor-welder.

b. Alternating-current welders (fig 2-40). Most ac welders are essentially static transformers. The function of a transformer, as the name implies, is to transform or change electrical power from one voltage to another. Basically, a transformer consists of three principal parts: a core, a primary coil, and a secondary coil. There are three general types of transformer arc welders: tapped reactor, movable coil, and movable core. The basic difference is the manner in which current control for welding is accomplished. Figure 2-40A illustrates a welder in which the current control is selected by inserting electrode and ground leads into appropriate receptacles. In the movable coil and movable core types (fig 2-40B), current is adjusted by manipulating a handwheel or crank. Before attempting to connect or operate a transformer welder, study the directions and the handbook for that unit as well as the information on the data plate. Then, before you apply power, be sure that:

(1) The transformer core and case are securely grounded.

(2) The secondary leads (electrode and work) are insulated from each other and from the ground.

(3) The correct voltage, as indicated on the nameplate, is used when connecting to the primary winding. Connecting the unit to direct current or to a power source having a greater voltage than that specified may result in serious damage to the transformer coil. To aid you in avoiding mistakes when connecting and grounding the welder, a 3-wire primary power source supply cable is furnished with each machine. Two leads, one black and one white, are for connection to the power source. The third is for grounding the transformer case and core to the established service ground. The grounding wire should always be connected to a ground before power is applied to the unit. Since there are no moving parts as in generator-type welders, transformer-type welders require less upkeep. However, the machine should and does require protection from dust, fumes, and excessive moisture. Also, the flow of ventilating air should not be restricted during operation. Once every 6 months the welder should be cleaned by blowing out the unit with clean, dry, compressed air. All welding operations with ac transformers must be done with heavily coated electrodes specifically designed for use with ac.

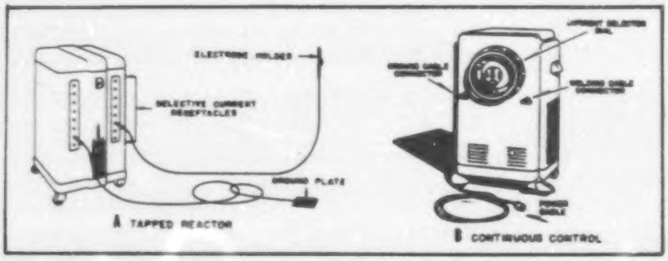


Fig 2-40. Ac transformer-type welding machines.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. A rectifier-type welding machine delivers __________ type current.

a. ac
b. dc
c. either a or c
d. polar

2. A LM-62 is a

a. gas-engine driven, self contained ac welder.
b. diesel engine-driven, self contained ac welder.
c. gas-engine driven, self contained dc welder.
d. diesel engine-driven, self contained dc welder.

3. The generator on the LM-62 welder provides _________ volts for operating the welder and small hand tools.

a. 110
b. 115
c. 220
d. 440

4. When the voltage required is critical for the operation of small hand tools from the electrical outlets on the LM-62 welder, the desired voltage may be regulated by the

a. engine speed.
b. job selector rheostat.
c. current control.
d. current control and polarity switch.

5. On the LM-62 welder, the welding generator and the attached exciter convert

a. dc to ac.
b. mechanical energy to electrical energy.
c. ac to dc.
d. mechanical energy to rotating energy.

6. Three factors determine the proper welding voltage and current selection on the LM-62 welder. They are, the material being welded, the skill of the welder, and

a. the current range of the welder.
b. the size of the electrode.
c. the polarity that will be used.
d. the rpm setting on the throttle control.

7. When welding in the overhead position using a 1/8 inch electrode, with the LM-62 welder, you would place the voltage control in the _________ section.

a. yellow
b. black
c. red.
d. special application

8. After cranking the LM-62 welder for 30 seconds, the starter should be allowed to cool for __________.

a. 30 seconds
b. 1 minute
c. 2 minutes
d. 3 minutes

9. The oil pressure gage should be checked after the engine has run for _________.

a. 10-20 seconds
b. 30 seconds
c. 1 minute
d. 2 minutes

10. Utilizing external power in the operation of a dynamotor-welder, _________ current is produced.

a. alternating
b. alternating and direct
c. direct

11. Electric transformer ac-type welders should be cleaned with compressed air every _________ month(s).

a. 2
b. 3
c. 5
d. 6

12. Match the fifteen gauges and controls (Column 1) with their correct uses (Column 2).

Column 1

(1) Hour meter.
(2) Fuel gage.
(3) Battle switch.
(4) Water temperature gage.
(5) Oil-pressure gage.
(6) Starter button.

Column 2

(a) This control varies the exciter voltage of the welding generator.
(b) The electrode holder and work cables are attached here to obtain welding current.
(c) It indicates engine lubricating oil pressure.

(7) Battery-charging ammeter.
(8) Panel light switch.
(9) Current control.
(10) Voltage control (job selector).
(11) Polarity switch.
(12) Utility outlets.
(13) Welding selector switch.
(14) Sigmette outlets.
(15) Welding generator terminals.

(d) It indicates total hours of engine operation.
(e) This switch permits the selection of the output terminals of the welding generator or sigmette outlet.
(f) It energizes the starting motor to crank the engine.
(g) Its purpose is to vary the current output of the welding generator.
(h) These outlets permit the welding of aluminum or small-gage metal.
(i) This switch disconnects all safety circuits to the engine.
(j) These supply voltage for small tools and accessories.
(k) It indicates the quantity of diesel fuel remaining in the tank.
(l) This switch controls the polarity of the electrode.
(m) It indicates the engine coolant temperatures.
(n) It turns on panel lights to illuminate controls and instruments.
(o) It indicates the charging or discharging rate of the battery.

Work Unit 2-5. WELDING PROCEDURES

IDENTIFY THE MEANS TO CONTROL EXPANSION AND CONTRACTION OF METAL DURING THE WELDING PROCESS.

IDENTIFY THREE METAL-ARC WELDING PROCEDURES.

IDENTIFY TWO ARC-WELDING SAFETY PRACTICES FOR ELECTRICAL SHOCK.

a. EXPANSION AND CONTRACTION IN WELDING OPERATIONS

(1) General. As you are probably aware, the linear dimensions of all metals change with fluctuations in temperature. The heat developed at the welded joint by any welding process will cause the metal to expand and, upon cooling, there will be a corresponding contraction or shrinkage. Just as metals differ in their ability to conduct heat, so do they vary in the extent to which their linear dimensions change with a given increase or decrease in temperature. The extent to which expansion and contraction occur influences the weldability of the metal involved. If all metals responded to temperature changes in the same way, the influence of expansion and contraction on weldability would be less than it is. But when metals having different rates of expansion and contraction are welded by high-temperature process, the internal stresses set up by different rates may cause the joint to crack immediately. Figure 2-41 illustrates some distortions caused by these internal stresses. Even when metals have the same characteristics, expansion and contraction may not be uniform throughout all parts of the metal. The nonuniformity of expansion and contraction will also lead to internal stresses, distortion, and warpage.

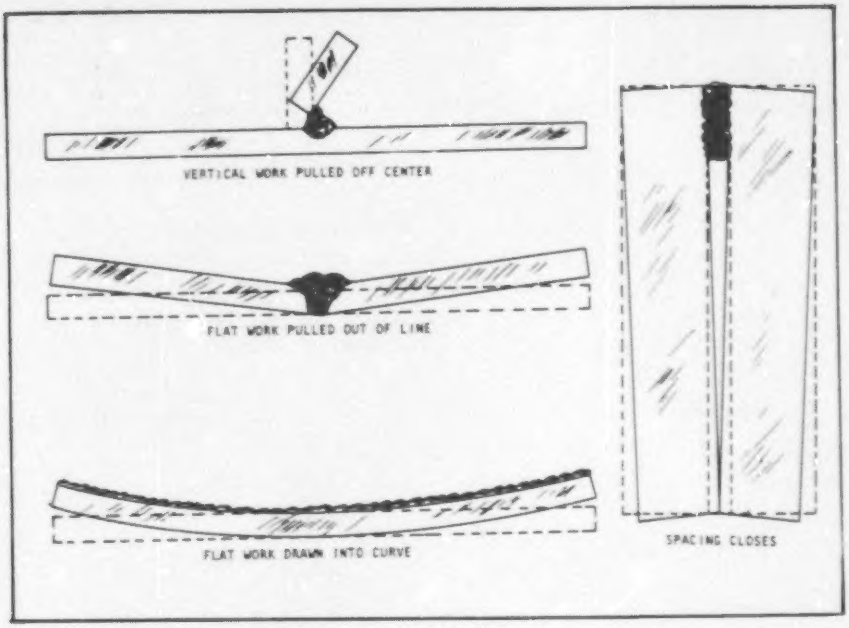

VERTICAL WORK PULLED OFF CENTER
FLAT WORK PULLED OUT OF LINE
FLAT WORK DRAWN INTO CURVE
SPACING CLOSES

Fig 2-41. Results of weld-metal shrinkage.

(2) Controlling expansion and contraction. The welding procedures should be devised so that contraction stresses will be held to a minimum in order to retain the desired shape and strength of the weld part. Tack welding helps to prevent undue distortion. You will usually tack-weld sheet-metal joints at short intervals. Most joints can be alined and held in place with pieces of angle iron and C-clamps. In welding long seams, the contraction of the metal deposited at the joint will cause the edges being welded to draw together and possibly overlap. This condition can be offset by wedging the edges apart as shown in figure 2-42. As the weld progresses, the wedge should be moved forward. Spacing of the wedge depends on the type of metal being welded and its thickness. Spacing for metals more than 1/8 in. thick is approximately as contained in table 2-2 below.

Table 2-2. Spacing of Metals to be welded.

Metal	Inches per foot
Steel	1/4 to 3/8
Brass and bronze	3/16
Aluminum	1/4
Copper	3/16
Lead	5/16

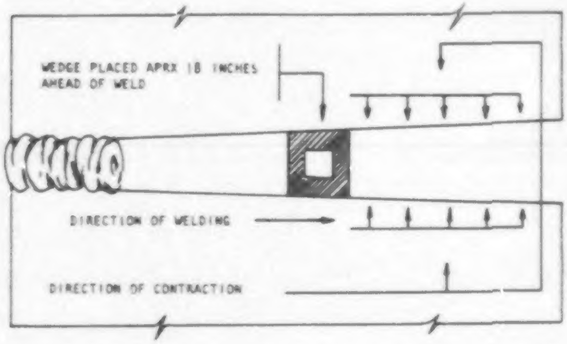

WEDGE PLACED APRX 18 INCHES AHEAD OF WELD
DIRECTION OF WELDING
DIRECTION OF CONTRACTION

Fig 2-42. Spacing with a wedge.

Buckling and warping can also be prevented by the use of quench plates. These are heavy pieces of metal clamped parallel to the seam being welded, with sufficient space between to permit the welding operation. These quench plates absorb the heat from the welding operation and decrease the stresses due to expansion and contraction.

(3) Stress-relieving. Upon cooling, the weld metal shrinks to a greater degree than the base metal to which it is welded and, because it is firmly fused to the base metal, it exerts a drawing action on it. This drawing action produces stresses in and about the weld which may cause warping and buckling. Therefore parts that cannot move to accommodate expansion and contraction must be heated uniformly during the welding operation and stress-relieved after welding. These precautions are particularly important in welding aluminum, cast iron, high-carbon steel, and other brittle metals. Stress-relieving in steel welds may be accomplished by heating the work from 800° to 1,450°F, depending on the material, and then cooling it slowly. In stress-relieving mild steel, it is common practice to heat the complete weld 1 hour for each inch of thickness. Another method of stress-relieving is to work the finished weld metal by hammer blows (peening). Excessive peening, however, may cause brittleness or hardening of the finished weld and actually cause cracking. Preheating of the parts to be welded is desirable in some applications of welding. If proper preheating times and temperatures are used, the cooling rate is slowed down sufficiently to prevent cracking. Preheating facilitates welding in many cases and prevents cracking troubles in the heat-affected zone particularly on the first passes of weld metal. The preheating temperatures for specific metals before welding are as contained in table 2-3 below.

Table 2-3. Preheating of Metal Before Welding.

Metal	Recommended preheating
Low-carbon steels (up to 0.25% carbon)	200° to 300°F
Medium-carbon steels (0.25% to 0.45% carbon)	300° to 500°F
High-carbon steels (0.45% to 0.90% carbon)	500° to 800°F
Carbon-molybdenum steels (0.10% to 0.30% carbon)	300° to 600°F
Carbon-molybdenum steels (0.30% to 0.35% carbon)	500° to 800°F
Manganese steels (up to 1.75% manganese)	300° to 800°F
Manganese steels (up to 15% manganese)	Usually not required.
Nickel steels (up to 3.50% nickel)	200° to 700°F
Chromium steels	300° to 500°F
Stainless steels	Usually not required.

Note: For alloy steels the preheating temperatures are governed by the carbon as well as the alloy content of the steel.

Cast iron	700° to 800°F
Aluminum	500° to 800°F
Copper	500° to 800°F
Nickel	200° to 300°F
Monel	200° to 300°F
Brass and bronze	300° to 500°F

b. METAL-ARC WELDING PROCEDURES

(1) General. Before you try your hand at metal-arc welding, equip yourself with the personnel protective clothing described earlier: helmet, gloves, etc. Also, consider the people around you by providing a screen to protect them from arc flashes. Further, be sure to ground your work piece or the welding table. Successful metal-arc welding requires the proper selection of electrodes for the kind and thickness of material to be welded as well as the type of welding current (ac or dc) to be employed, and the position in which welding is to be accomplished. Welding equipment controls for amperage, voltage, and polarity must be adjusted to provide the current value suitable for the conditions of welding, including the skill of the welder himself. No specific directions are given here for setting the controls because they vary on the different types and sizes of machines made by different manufacturers. Get an experienced welder to break you in on the machine you will be using. As you gain experience, you will learn to make your own adjustments. Experience is the best guide for making the necessary adjustments to fulfill the job requirements. For the first setting of the machine you can use those settings shown in figure 2-43 as a guide. Usually the containers in which the electrodes are furnished by the manufacturer have instructions for their use as to the recommended welding current setting for various sizes of electrodes and positions of welding. Bear in mind that you can only use those recommendations as a guide. Exact adjustments depend on your welding skill and the type of machine you are using.

Electrode size (in.)	Class	Plate thickness (in.)	Amperes Ac	Amperes Dc
3/32	1	3/16	70	80
1/8	1	1/4	110	120
5/32	1	1/4	135	150
3/16	1	1/2	155	180
7/32	2	1/2	175	215
1/4	2	1/2	225	240

Fig 2-43. Current settings for welding steel with 6011 electrodes.

The mineral-coated type of shielded-arc electrode, which produces a slag as a shield, requires higher welding currents than does the cellulose-coated type, which produces large volumes of gases to shield the arc stream. In addition to proper adjustments for current and voltage, to give proper welding conditions for the particular size and type of electrode used, it is necessary to consider polarity. The proper polarity can be recognized by the sharp crackling sound of the arc. Improper polarity for a given electrode will cause the arc to give off a hissing sound and will make control of the weld difficult. After the machine has been properly adjusted, the bare end of the electrode should be gripped in the electrode holder so that the entire length may be consumed and deposited without breaking the arc. There are two ways of getting the arc started after you have properly set up and adjusted your welding machine; the striking or brushing method, and the tapping method. In either method, the arc is formed by short-circuiting the welder current between the electrode and the joint to be welded. The heat at the arc causes both the end of the electrode and the spot struck on the metal to melt instantly. In the striking or brushing method (fig 2-44), the end of the electrode is brought down to the work in a continuous motion that describes the arc of a circle. As soon as you touch the surface of the base metal, the downward motion is checked and the electrode is raised to make the arc. The distance between the electrode and the base metal should be about equal to the diameter of the electrode. You will know by the sharp crackling sound when you have the right length arc. In the tapping method (fig 2-45), you hold the electrode vertical to the plate. Establish the arc by lowering the electrode and tapping or bouncing it on the surface of the

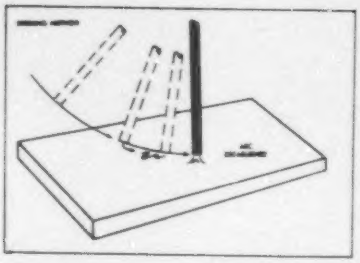


Fig 2-44. Striking or brushing method.

base metal. With some types of electrodes it is necessary to strike the electrode forcibly on the base metal to remove the projecting cover on the electrode tip. With other types, you only need to hold the electrode in contact with the work. The coating of these contact electrodes is an electrical conductor of sufficient degree to start an arc. The arc is maintained by keeping the covering in contact with the work. When you strike an arc, be sure not to raise the electrode too fast or you will lose the arc due to its length. If you raise it too slowly, it will stick or freeze to the base metal. When this happens, you can usually free it by a quick sidewise wrist motion. If the electrode is not freed by this motion, remove the holder from the electrode or stop the machine. A light chisel blow will then free the electrode and allow it again to be gripped in the holder. Do not remove your helmet or the shield from your eyes while working with the electrode. After the arc is struck, particles of metal melt off the end of the electrode and are fed into the molten crater of the base metal. This causes the electrode to shorten and the arc to increase in length unless you keep the electrode closer to the base metal as the end is fed off. If the electrode is fed down to the plate and along the surface at a constant rate, a bead of metal will be deposited or welded onto the surface of the base metal. Before you advance your arc, hold it for a short time at the starting point to insure good fusion and to build up the bead slightly. Good arc welding depends on good control of the motion of the electrode down to and along the surface of the base metal. Just as there are two different methods for starting the arc, there are also two different methods of breaking the arc. In the first method, the arc is shortened and the electrode is moved quickly, sideways from the crater. In the second method, the electrode is held stationary long enough to fill the crater and then slowly withdrawn. Usually, the first method is the one that you will use. In general, the types of welds and joints for arc welding are the same as those used in gas welding. Also, the positions of welds are the same as in gas welding. Arc-welding techniques must differ somewhat for the positions used. The position of the electrode in relation to the joint is a factor of prime importance. Increasing the electrode angle, in the direction of welding builds up a bead.

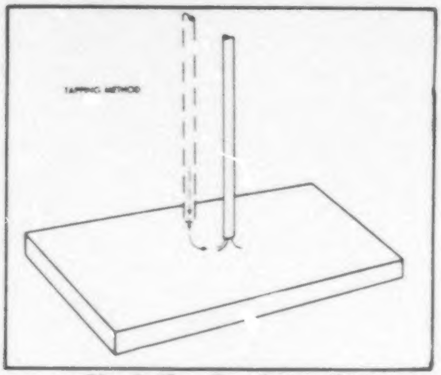


Fig 2-45. Tapping method.

(2) Welding a bead in the flat position (fig 2-46). The electrode should be held at a 90° angle to the base metal. In order to get a good view of the molten puddle, you may find it convenient to tilt the electrode from 5° to 15° in the direction of the welding. To run a bead, don't move the electrode from side to side. To keep the arc constant, move the electrode forward just fast enough to deposit the weld metal uniformly, and move it downward as rapidly as the molten metal is deposited. Hold a short arc and weld in a straight line at a constant speed. You can't judge the proper length of the arc by looking at it, so you will have to depend on recognizing the sound made by the short arc. This is a sharp crackling sound and it should be heard all during the time the arc is being moved along the surface of the plate. When the length of the weld requires the use of more than one electrode, reestablishing the arc and continuing the weld becomes an important procedure. Reestablish the arc by striking the tip at the forward or cold end of the weld crater; then move the arc backward over the crater and then forward again to continue the weld. This procedure fills the crater and avoids porosity and tapping of slag.

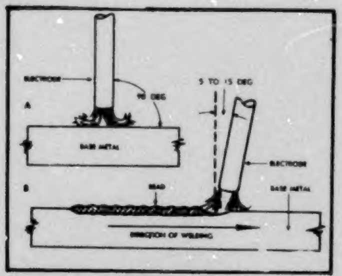


Fig 2-46. Electrode position for welding a bead in the flat position.

A good bead weld should have the following characteristics (see fig 2-47):

Little or no weld spatter on the surface of the plate.

An arc crater in the bead of approximately 1/16 in. when the arc has been broken.

Slight build up bead with no metal overlap at the top surface.

A good penetration of approximately 1/16 in. into the base metal.

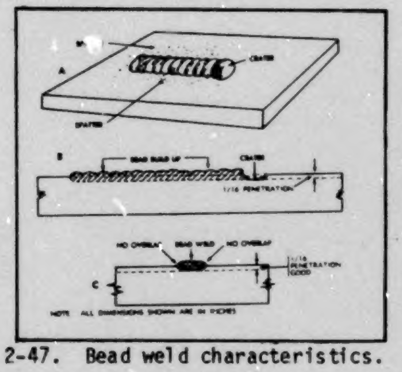


Fig 2-47. Bead weld characteristics.

(3) Welding a butt joint in the flat position. The setup for this type of weld is the same as for gas welding. Plates less than 1/4 in. thick can be welded in one pass. No edge preparation is necessary for this type of weld, but the edges of the base metal should be tacked together to prevent them from separating and to keep them alined. The electrode motion is the same as for forming a bead in the flat position, When you are welding plate more than 1/4-in. thick, the edges should be prepared by beveling or U-grooving. Any of the joint designs illustrated earlier may be used, depending on the thickness of the plates. The first bead or root is deposited to seal the space between the two pieces of the joint and to weld the root of the joint. The bead must be thoroughly cleaned to remove all slag before another pass is made. The second, third, and fourth layers of weld metal are sometimes deposited in a weaving motion. Any of the methods shown in figure 2-48 may be used, depending on the type and size of electrode. You will have to clean

each layer before depositing the next, and you will have to be careful to prevent undercutting. To prevent this, pause at the end of each turn of the weave on the edges of the joint. If you have trouble getting good penetration at the root of the butt joint in the flat position, you will have to use a backup strip (fig 2-29). Tack-weld the strip to the base of the joint and use it as a cushion for the first layer of weld metal. When the weld is completed you can remove the strip and add a seal bead at the back, if necessary.

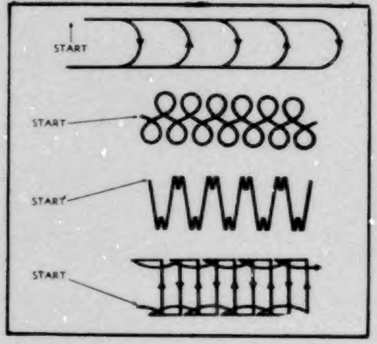

START
START
START
START

Fig 2-48. Weave motions.

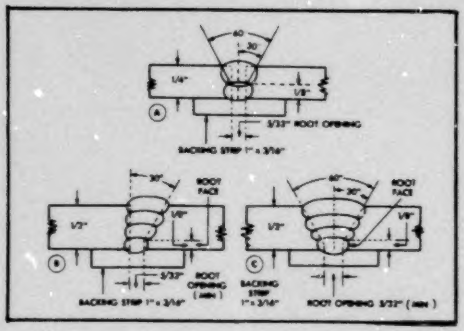

60
30°
1/4"
1/8"
A
3/32" ROOT OPENING
BACKING STRIP 1" x 3/16"
30°
ROOT FACE
1/2"
1/8"
B
3/32"
ROOT OPENING (MIN)
BACKING STRIP 1" x 3/16"
60°
30°
ROOT FACE
1/2"
1/8"
C
BACKING STRIP 1" x 3/16"
ROOT OPENING 3/32" (MIN)

Fig 2-49. Butt welds with a backup strip.

(4) Fillet welds on T-joints and lap joints. Electrode lead and work angles are particularly important in joint designs requiring fillet welds. The angular position of the electrode determines the freedom from undercutting, the case with which the filler metal is deposited, and the uniformity of penetration and weld appearance. The lead angle is the angle between the electrode and the joint in the direction in which the welding is being done. Work angle is the angle between the electrode and the work in a plane normal to the joint plane. Both types are shown in figure 2-50. Fillet welds, as you may recall, are used to make T-joints. To set up a T-joint in the flat position, you form an angle of 90° between surfaces of the two pieces of plate being welded. First, tack-weld them in position by welding a tack at the ends. Use a short arc, and hold the electrode at a work angle of 45° to the plate surfaces (fig 2-51). Tilt your electrode to about 15° lead angle in the direction of welding. Light plates can be used without a weaving motion of the electrode, and they can be welded in one pass. Heavier plates may take two or more passes; if they do, a semicircular weaving motion is

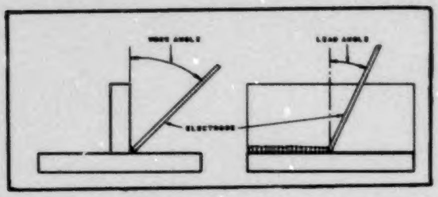

WORK ANGLE
LEAD ANGLE
ELECTRODE

Fig 2-50. Electrode lead and work angles.

used with the second pass to get good fusion without undercutting. Lap joints are made in the same way as T-joints, except that the electrode should be held so as to form a 30° angle with the vertical. The angle is more nearly straightened upward than that used for the T-joint.

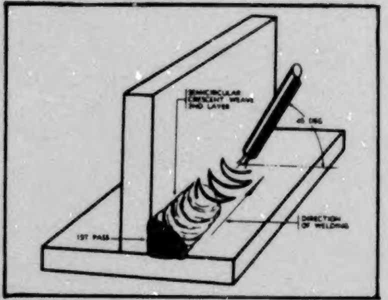


Fig 2-51. Fillet welding a T-joint.

(5) Arc welding in the overhead position (fig 2-52). This is a difficult position for some welders. The following tips will help you to get a good overhead weld:

Keep a short arc. This will help you to retain complete control of the molten pool.

Hold the arc at 90° to the base metal when welding a bead.

Avoid excessive weaving in the overhead position as this will cause overheating of the weld metal and form a large pool which is hard to control.

Butt joints in the overhead position are best made with backup strips. Where backup strips are not permitted, the root can be welded from the top side. String (straight-line) beads are better than weave beads for this type of weld, but each bead must be cleaned and the rough areas should be chipped out before the next pass is made. Figure 2-52 illustrates the proper sequence for running beads. Fillet welding in the overhead position (fig 2-53) is done with a short arc and no weaving. Hold the electrode about 30° from the vertical plate and move it uniformly in the direction of welding. Control the arc motion to get good root penetration and good fusion with the sidewalls. If you get too big a pool of molten metal and it begins to sag, whip your electrode away from the crater, ahead of the weld, lengthening the arc and allow the metal to solidify. Then return the electrode immediately to the crater and continue to weld. Heavy plate may require several passes to make either the T-joints or lap joints in the overhead position. The second, third, or fourth pass is made with a slight circular movement of the end of the electrode while the top of the electrode is tilted about 15° in the direction of welding. Each bead must be chipped and cleaned before the next bead is applied. Chipping and wire brushing is the best method for cleaning.

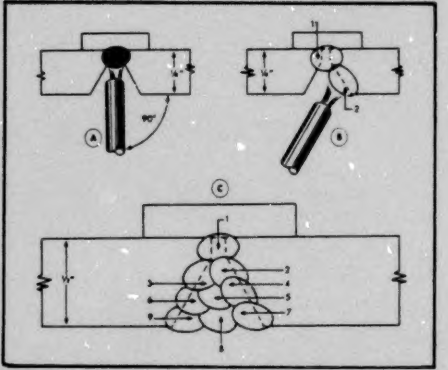


Fig 2-52. Welding butt joints in the overhead position.

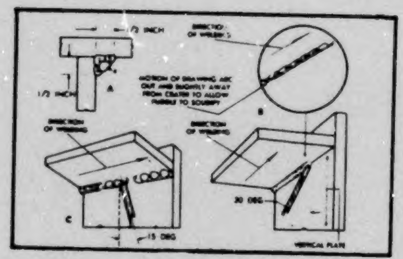

1/2 INCH
DIRECTION OF WELDING
1/2 INCH
A
MOTION OF DRAWING ARC OUT AND SLIGHTLY AWAY FROM CRATER TO ALLOW PUDDLE TO SOLIDIFY
B
DIRECTION OF WELDING
DIRECTION OF WELDING
30 DEG
C
15 DEG
VERTICAL PLATE

Fig 2-53. Fillet welding in the overhead position.

(6) Welding in the vertical position (fig 2-54). Because of the tendency for the molten metal to run down, welding in the vertical position is much more difficult than the flat position. Here again, careful control of the welding voltage as well as a short arc is necessary. Current setting or amperage is less for welding in the vertical position than for welding in the flat position. Less current is used for welding down than for welding up in the vertical position. When welding up, hold the electrode at 90° to the vertical, and when welding down, hold the electrode about 15° from horizontal in the direction of welding (fig 2-54C). Butt joints welded in the vertical position are best made with a triangular motion (fig 2-55). If these joints are of 1/2 in. or heavier plate, several passes will be required to get a good weld joint.

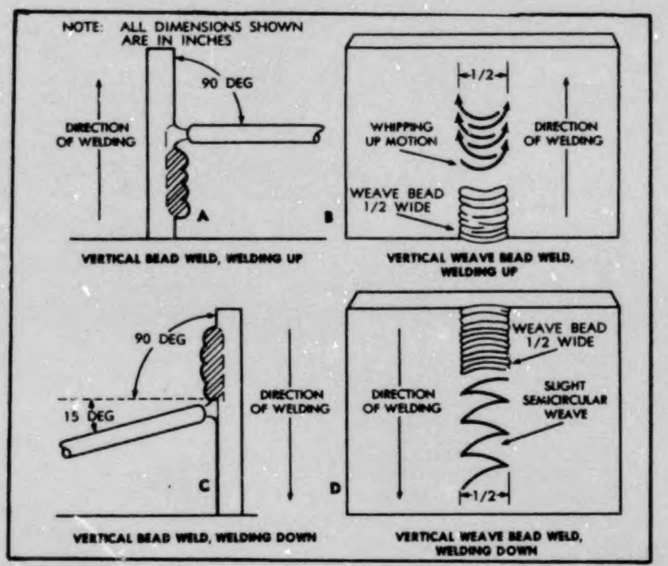

NOTE: ALL DIMENSIONS SHOWN ARE IN INCHES
90 DEG
DIRECTION OF WELDING
A
VERTICAL BEAD WELD, WELDING UP
1/2
WHIPPING UP MOTION
DIRECTION OF WELDING
WEAVE BEAD 1/2 WIDE
B
VERTICAL WEAVE BEAD WELD, WELDING UP
90 DEG
15 DEG
DIRECTION OF WELDING
C
VERTICAL BEAD WELD, WELDING DOWN
WEAVE BEAD 1/2 WIDE
DIRECTION OF WELDING
SLIGHT SEMICIRCULAR WEAVE
1/2
D
VERTICAL WEAVE BEAD WELD, WELDING DOWN

Fig 2-54. Welding in the vertical position.

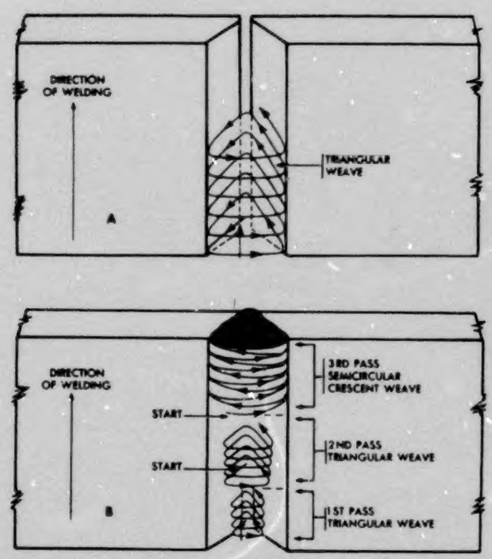

DIRECTION OF WELDING
TRIANGULAR WEAVE
A
DIRECTION OF WELDING
3RD PASS SEMICIRCULAR CRESCENT WEAVE
START
START
2ND PASS TRIANGULAR WEAVE
1ST PASS TRIANGULAR WEAVE
B

Fig 2-55. Welding a vertical butt joint with a triangular weave.

Sucessful manual arc welding depends on many factors, but the most important part of the procedure is electrode manipulation. The arc must be neither too long nor too short. Too long an arc causes excessive arc spatter. It also decreases the protection of the gaseous shield at the tip of the electrode. Too short an arc is also unstable due to the tendency to short circuit and freeze. During arc welding, electrode manipulation must insure that the sidewalls of the joint are being melted and the weld metal is properly bonding without undercutting or overlapping. Another objective of electrode manipulation is complete penetration, especially at the root. To gain the skill you need requires a great deal of practice. Knowledge about a subject is useful in solving problems, but when it comes to producing a sound weld it requires skillful manipulation techniques. This information can provide guidance, but only your own efforts can produce the skill.

c. ARC-WELDING SAFETY PRACTICES

Safety consciousness, an awareness of possible hazards, and knowledge of ways to avoid or control dangerous conditions are essential in any work. In welding, ignorance of safe practice or carelessness in the application of safety rules may result in serious injury or death for those personnel involved. Before you set up, operate, or attempt to weld, you should be thoroughly familiar with all applicable safety rules and practices. There is a Navy publication which discusses in detail the safety precautions that must be observed in welding, the principal hazards that exist, and methods to eliminate these hazards. This publication, Safety Precautions for Shore Activities, NAVMAT P-5100, chapter 10 should be read and studied at your first opportunity. This publication forms the basis of the safety program within which you will do your welding. Fo the purpose of the present discussion, it is assumed that only authorized equipment, in good condition, properly handled, properly set up and operated, is employed in welding operations. In common with other electrical devices, the electric welding machines discussed earlier in this chapter are a sourse of potential danger from electric shock. This hazard can be minimized by maintaining the equipment in good mechanical and electrical condition. In addition to good maintenance, it is important to realize that any electrical circuit, whether it is high or low voltage, must be handled with utmost caution. One of the principal dangers from welding circuits is to erroneously assume that, since they are of low voltage, they can be handled without the hazard of dangerous shock. This is not true, and particularly so if your body is damp from sweat or wet from rain. To avoid this situation, make it a practice to keep your body dry and insulated from both the work and the electrodes or electrode holders. Never assume that because a contact at one time was not harmful that similar contacts at other times will also be harmless. Treat electricity with respect, and play it safe.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Select the metal that would require the greatest separation when you are spacing sheet metal to control expansion and contraction.

   a. Bronze
   b. Aluminum
   c. Copper
   d. Brass

2. When welding sheet metal, the purpose of quench plates clamped parallel to the seam is

   a. to act as a backup plate for reinforcement.
   b. to decrease expansion and contraction by absorbing the heat.
   c. to hold the metal in place for welding.
   d. to serve as deflectors for sparks.

3. When welding parts that cannot be moved to accommodate expansion and contraction, they must be

   a. galvanized.
   b. soaked.
   c. stress-relieved.
   d. cooled.

4. The recommended preheat temperature range for a cast-iron pump housing is

   a. 200 - 300°F.
   b. 300 - 500°F.
   c. 300 - 600°F.
   d. 700 - 800°F.

5. All of the metals listed below would require preheating EXCEPT

   a. chromium steel.
   b. stainless steel.
   c. nickel-chromium steel.
   d. high-carbon steel.

6. When welding with a dc electrode, you can tell the correct polarity is being used by

   a. a hissing sound made by the arc.
   b. a sharp crackling sound made by the arc.
   c. an excessive amount of weld splatter.
   d. the absence of weld splatter.

7. When welding two plates horizontally, you should usually hold the electrode at a __________ angle to the bare metal, with a __________ tilt in the direction of welding.

   a. 30° -- 20°
   b. 90° -- 20°
   c. 90° -- 5° to 15°
   d. 5° -- 15° to 90°

8. The angular position in which the electrode is held, when welding joints requiring fillet welds, influences welding operations by

   a. allowing the welder to see the weld bead.
   b. determining the freedom from undercutting.
   c. reducing the amount of slag present in the weld hose.
   d. determining the amount of filler metal applied to the base metal.

9. While welding in the overhead position, you should ______________ when the metal sags.

   a. shut off the welder
   b. maintain a short arc
   c. continue to weld, and chip off excessive metal
   d. whip the electrode away momentarily to allow the metal to cool

10. Good penetration is considered to be

    a. 1/32 in.
    b. 1/16 in.
    c. 1/8 in.
    d. 1/4 in.

11. The most dangerous hazard you must consider when working with welding circuits is

    a. work material falling on you.
    b. an explosion caused by the arc.
    c. burns received by hot metal.
    d. severe electrical shock.

12. Awareness of possible hazards, knowledge of ways to avoid or control dangerous conditions and __________ are essential in any work.

    a. safety consciousness
    b. safety rails
    c. type of metal
    d. the position used

SUMMARY REVIEW

In this study unit you learned to identify the basic elements of electricity in arc welding. You learned the construction and types of welds: arc welding machine accessories, arc welding procedures, and welding safety practices.

Answers to Study Unit #2 Exercises.

Work Unit 2-1

1. a.
2. c.
3. a.
4. a.
5. c.
6. c.
7. a.
8. a.
9. c.

Work Unit 2-2.

1. a. Root
   b. Toe
   c. Face
2. a.
3. The region of base metal that is actually melted.
4. a.
5. b.
6. d.
7. c.
8. a.
9. d.
10. c.
11. b.
12. d.
13. c.
14. a. Bead
    b. fillet
    c. groove
    d. Tack
    e. plug/slot
15. c.
16. d.
17. a.
18. b.
19. e.

Work Unit 2-3.

1. b.
2. Any device that protects the welder from intense light, reflected glare, radiated heat, and flying particles of hot metal.
3. c.
4. d.
5. c.
6. d.
7. d.
8. c.
9. c.
10. b.

11. a. Represents the word "electrode".
    b. First two numbers represent the tensile strength of the deposited weld in 1,000 pounds per square inch.
    c. Represents the position in which the electrode may be applied.
    d. Indicates one of the seven subgroups (see para 2-3e, end of paragraph.)

12. a. Welding machine
    b. Flexable cables
    c. Electrode holders
    d. Protective devices
    e. Chipping hammers
    f. Wire brushes
    g. Welding tables
    h. Backup bars
    i. Electrode

Work Unit 2-4.

1. a.
2. d.
3. b.
4. a.
5. b.
6. c.
7. c.
8. c.
9. a.
10. c.
11. d.
12. (1) d.
    (2) k.
    (3) i.
    (4) m.
    (5) c.
    (6) f.
    (7) o.
    (8) n.
    (9) g.
    (10) a.
    (11) l.
    (12) j.
    (13) e.
    (14) h.
    (15) b.

Work Unit 2-5.

1. b.
2. b.
3. c.
4. d.
5. b.
6. b.
7. c.
8. b.
9. c.
10. b.
11. d.
12. a.

STUDY UNIT 3

GAS-WELDING PROCESSES

STUDY UNIT OBJECTIVE: UPON SUCCESSFUL COMPLETION OF THIS STUDY UNIT, YOU WILL IDENTIFY OXYACETYLENE WELDING EQUIPMENT, PROCEDURES OF OXYACETYLENE BRAZING, WELDING AND CUTTING OF METALS, GAS-WELDING SAFETY PRECAUTIONS, WELDING EQUIPMENT TROUBLESHOOTING, AND INERT GAS-ARC WELDING PROCEDURES.

Oxacetylene welding is a gas-welding process in which the necessary heat is obtained by burning a mixture of oxygen and acetylene. These two gases are mixed in the desired proportions in a torch which can be controlled by the operator to provide any required flame adjustments. In general, the edges to be welded by this process must be properly prepared, and consideration must be given to the correct spacing and alinement of the parts. A good weld requires a proper torch tip size, correct flame adjustment, and skillful rod and torch manipulation. Under some conditions, special procedures are necessary, such as preheating and slow cooling (chap 1, see IV) and stress-relieving after welding. For welding some metals, a flux is required to remove oxides and slag from the molten metal and to protect the puddle from the action of oxygen from the air. For welding light sheet metal, the edges must be prepared in a butt joint. No filler metal is required for light sheet metal. For welding heavy sheets and plates, filler metal is required and the edges of the seam must be prepared to permit penetration of the filler metal into the root of the joint.

Work Unit 3-1. OXYACETYLENE WELDING EQUIPMENT

IDENTIFY TWO GAS CYLINDERS USED IN OXYACETYLENE WELDING BY COLOR CODE.

IDENTIFY THE PRESSURE RANGES ON THE TWO HIGH-PRESSURE GAUGES USED IN OXYACETYLENE WELDING.

The equipment used for oxacetylene welding consists of a source of oxygen and acetylene, together with two regulators, two hoses, and a welding torch with a cutting attachment or a separate cutting torch. In addition, suitable goggles are required for eye protection, gloves to protect the hands, and wrenches for the various connections on the regulators, torches, and cylinders.

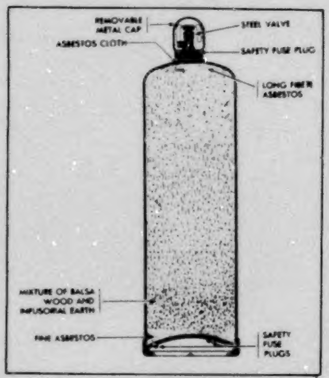


Figure 3-1. Acetylene cylinder.

a. Acetylene cylinders (fig 3-1). Acetylene is a fuel gas made of carbon and hydrogen (C_2H_2). When burned with oxygen it produces a very hot flame of a temperature between 5,700° and 6,300°F. Acetylene is colorless, but it has an odor that is easy to distinguish. Acetylene stored in a free state under pressure greater than 15 psi can be made to break down by heat or shock, and will explode. Under a pressure of 29.4 psi, acetylene becomes self-explosive and the slightest shock will set it off. However, when dissolved in acetone, it can be compressed into cylinders at pressures up to 250 psi. The acetylene cylinder shown in figure 3-2 is filled with porous materials, such as balsa wood, charcoal, shredded asbestos, corn pith, portland cement, or infusorial earth. Infusorial earth is a absorbent material composed of decayed organic matter. It is used to decrease the size of the open spaces in the cylinder. Acetone, a colorless, flammable liquid, is added until about 40% of the porous material is filled. The filler acts as a sponge and absorbs the acetone, which in turn absorbs the acetylene. When acetylene is used from a cylinder, it should not be drawn off at a continuous rate in volumes greater than 50 cu ft per hour. The precaution is necessary to prevent the drawing off of the acetone and consequent impairment of the quality of the weld. Acetylene cylinders are equipped with safety plugs having a small hole in the center that is filled with an alloy that melts at approximately 212°F. In case the cylinders overheat, these plugs will melt and permit the acetylene to escape before a dangerous pressure can be built up. The holes are also too small to permit a flame from burning back into the cylinders, should the escaping gas become ignited.

b. Industrial gas identification. Because of the many types of industrial gases that are bottled and used for various types of operation , a rigid color code has been established making it practically impossible to confuse gases and mistake one gas cylinder for another. Industrial gases have been divided into eight classes each with a basic color. Industrial gases are always marked with a basic color of tan; medical, blue; toxic materials, brown; refrigerants, orange; fuel, yellow; fire fighting, red; inert, gray; and oxidizing, black, except for oxygen which is green. Acetylene, which is a fuel gas, is always in a cylinder painted yellow with the name of the gas stenciled lengthwise on two sides of the cylinder in 2 inch letters. Two 3 1/2- x 2 1/2-in. oval decals are affixed to opposite shoulders of the bottle to show the name of the gas and necessary precautions for its use and handling. Bottles should never be painted any color other than those indicated above. If it becomes necessary to camouflage bottles, either use drape nets or make covers for the bottles and then camouflage the covers.

c. Oxygen cylinders (fig 3-2). Oxygen is supplied in green bottles and marked to indicate oxygen. Oxygen is tasteless, colorless, odorless gas that is slightly heavier than air. It is nonflammable, but when combined with other elements it will support combustion. Oxygen in its free state is one of the most common elements. The atmosphere in which you breathe is made up of approximately 21 parts of oxygen and 78 parts of nitrogen, the rest being rare gases. When supplied for use in oxyacetylene welding operations, oxygen is contained in a seamless steel cylinder (fig 3-2) which has a capacity of 220 cuft of oxygen at a pressure of 2,000 psi at a temperature of 70°F. Remember that anytime oxygen comes in contact with oils or greases under pressure, it will ignite violently. For this reason, DO NOT lubricate any oxyacetylene equipment. This includes cylinders, valves, regulators, hoses, or any other apparatus. Remove any traces of grease from your hands when working with oxyacetylene equipment.

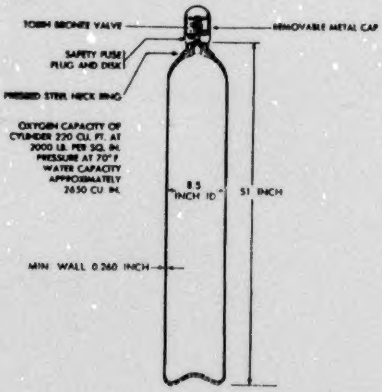

TOBIN BRONZE VALVE
REMOVABLE METAL CAP
SAFETY FUSE PLUG AND DISK
PRESSED STEEL NECK RING
OXYGEN CAPACITY OF CYLINDER 220 CU. FT. AT 2000 LB. PER SQ. IN. PRESSURE AT 70° F WATER CAPACITY APPROXIMATELY 2650 CU. IN.
8.5 INCH ID
51 INCH
MIN WALL 0.260 INCH

Fig 3-2. 220-cu ft oxygen cylinder.

d. Regulators (fig 3-3). The gas pressure in the oxygen and acetylene bottles is too high for normal usage and must therefore be reduced to a pressure suitable for working. This is accomplished by the use of regulators. There are two types of regulators, single-stage and 2-step. The difference between the two types is that the single-stage reduces the gas pressure in one step and the 2-step performs the same work in two stages and less adjustment is necessary. The one that is used most frequently and the one that you will come into contact with will be the single-stage regulator (fig 3-3). The regulator mechanism consists of a nozzle through which the high-pressure gases pass, a valve seat to close off the nozzle, a diaphragm, and balance springs. Pressure gases are provided to indicate the pressure in the cylinder as well as the working pressures. The inlet gage is a high-pressure gage which records cylinder pressure. The outlet gage is a low-pressure gage which records the working pressure. The acetylene regulators are of the same type as the oxygen, but are not designed to withstand the high pressure as are those used with oxygen. In the oxygen regulator, the oxygen passes through a glass wool filter on the high-pressure inlet side, which filters out dust and dirt. Turning the adjusting screw in allows the oxygen from the high-pressure side to flow to the low-pressure chamber of the regulator, through the regulator outlet to the hose. Turning the adjusting screw to the right increases the working pressure, and turning it to the left decreases the working pressure. On the oxygen regulator, the high-pressure gage is graduated from 0 to 3,000 psi; on the acetylene regulator, it is graduated in cubic feet from 0 to 220. This permits determining cylinder pressure and cubic content. The gages are graduated to read correctly at 70°F. The working pressure gage is graduated in psi from 0 to 50, 0 to 200, and 0 to 400, depending on the purpose for which the regulator is designed. For example, regulators designed for heavy cutting have gases graduated from 0 to 400 psi.

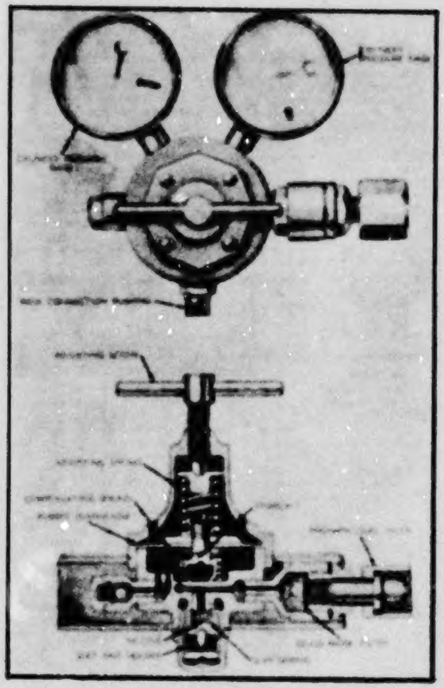
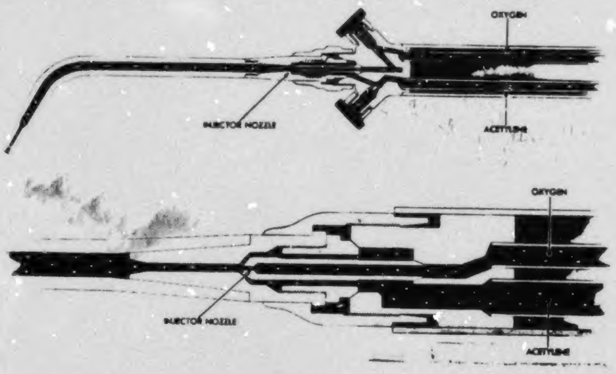
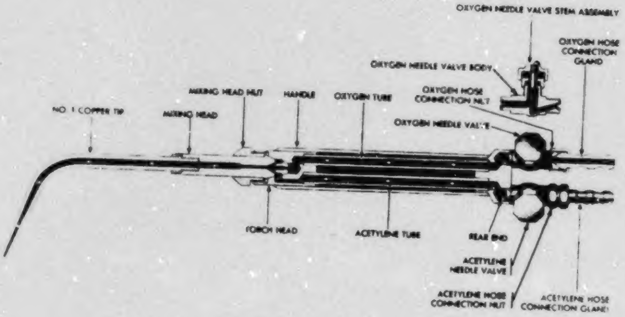


Fig 3-3. Single-stage regulator.

e. Welding torches (fig 3-4). The oxyacetylene welding torches are used to mix the oxygen and acetylene gases in the proper proportions and to control the volume of these gases at the welding tip. Torches have two needle valves, one for adjusting the flow of oxygen and one for adjusting the flow of acetylene. In addition they have a handle, two tubes (one each for oxygen and acetylene), a mixing head, and a tip. The tubes are silver-brazed to the head and the rear end forgings, which in turn are fitted into the handle. Welding tips are made of copper and come in various sizes to handle a wide range of plate thicknesses. There are two


OXYGEN
INJECTOR NOZZLE
ACETYLENE
OXYGEN
INJECTOR NOZZLE
ACETYLENE

A. Low-pressure torch


OXYGEN NEEDLE VALVE STEM ASSEMBLY
OXYGEN HOSE CONNECTION GLAND
OXYGEN NEEDLE VALVE BODY
OXYGEN HOSE CONNECTION NUT
MIXING HEAD NUT
HANDLE
OXYGEN TUBE
NO. 1 COPPER TIP
MIXING HEAD
OXYGEN NEEDLE VALVE
TORCH HEAD
ACETYLENE TUBE
REAR END
ACETYLENE NEEDLE VALVE
ACETYLENE HOSE CONNECTION NUT
ACETYLENE HOSE CONNECTION GLAND

B. Equal-pressure torch

Fig 3-4. Welding torches.

types of welding torches, low-pressure and equal-pressure . In low-pressure type (fig 3-4A) the acetylene pressure is less than 1 psi. A jet of high-pressure oxygen is necessary to produce a suction effect which draws in the required amount of acetylene. This is accomplished by the design of the mixer which operates on the injector principle. The welding tips may or may not have separate injectors designed into the tip. In the medium- or equal-pressure torch (fig 3-4B) the acetylene is burned at pressures from 1 to 15 psi. These torches are made to operate at equal pressures for acetylene and oxygen. They are easier to adjust and, because of the equal pressures used, you are less likely to get a flashback. This means that the flame is less likely to catch in or in back of the mixing chamber. Welding tips and mixers are made by different manufacturers and differ in design. Some makes of torches are provided with an individual mixing head for each tip. Others have one mixer for different size tips. Some are 1-piece, hard copper tips. Others are 2-piece and include an extension tube to make a connection between the tip and the mixing head. Tip sizes are designated by numbers; each manufacturer has his own arrangement for marking them. Tip sizes differ in the diameter of the hole to obtain the correct volume of heat for the work to be done. No matter what size tip you use, in order to obtain the right flame and keep it burning properly, it must be kept clean. Quite often these orifices (holes) become clogged. Obstructions can be removed by the use of tip cleaners (small wires of the proper diameter). Tips should not be cleaned with drill bits or hard, sharp instruments, as these tend to increase hole size and thus reduce efficiency.

f. Setting up and operating equipment. In setting up and operating oxyacetylene equipment, a fire extinguisher should be available in the event of an emergency. Remember that you are working with a gas mixture that is highly flammable and explosive. Remove the cylinder caps and open the valve on each cylinder slightly. This will blow out any dirt or obstruction that may be lodged in the outlet nipples. Attach the regulators to their respective cylinders and tighten the union nuts with the apparatus wrench. Pay particular attention to these regulators; do not attach an acetylene regulator to an oxygen cylinder. To prevent this, the majority of acetylene cylinders are equipped with outlet valves with left-handed threads. Attach the red acetylene hose to the acetylene regulator; both of these attachments have left-handed threads to prevent mismatching hoses and regulators as well as torch controls. Attach the green oxygen hose to the oxygen regulator; the threads on these attachments are right-handed and tighten with the apparatus wrench. Release the regulator adjusting screws by turning them counterclockwise until they are loose. Open the acetylene tank valve to a maximum of 1 1/2 turns, (1/4 to 1/2 turn is NORMALLY sufficient). Open the oxygen tank valve to full open. Never open these valves until you have released the regulator adjusting screws. Blow out each hose one at a time by turning the regulator adjusting screws clockwise. After you have done this, release the adjusting screws. Connect the hoses to the torch, red hose to the connection gland marked AC, and green hose to the gland marked OX. Here again you encounter left-handed threads on the acetylene connections and right-handed threads on the oxygen connections. Select the proper tip size and attach to the torch. Tighten the tip moderately. To adjust the regulators for the working pressures of the gases, open first the acetylene torch needle valve and adjust the regulator to obtain the correct pressure, then close the valve and adjust the oxygen working pressure in the same manner. Working pressures will differ for the type of work being performed and the tip size.

g. Flame adjustment. To light the torch, open the acetylene needle valve and light the torch. When the torch is first lit, there is not enough oxygen to provide complete combustion; therefore, the flame is long and bushy and yellowish in color. Before opening the oxygen valve, adjust the acetylene until the pure acetylene flame leaves the end of the tip so that the base of the flame is approximately 1/16" to 1/8" away from the face of the tip. At this adjustment the flame is stable and free from flashbacks and backfires. Open the oxygen valve slowly until the flame changes to a bluish-white color and forms a bright inner cone surrounded by an outer flame envelope or sheath flame. The next step is to begin to weld.

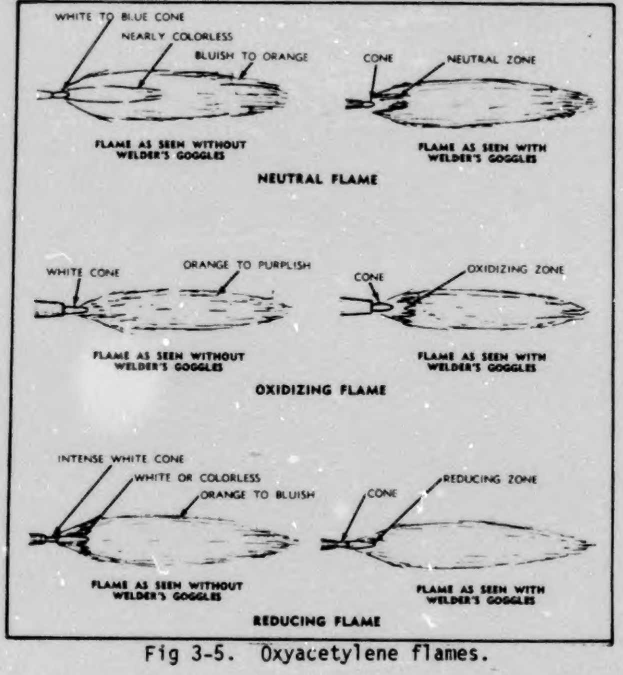

WHITE TO BLUE CONE
NEARLY COLORLESS
BLUISH TO ORANGE
CONE
NEUTRAL ZONE
FLAME AS SEEN WITHOUT WELDER'S GOGGLES
FLAME AS SEEN WITH WELDER'S GOGGLES
NEUTRAL FLAME
WHITE CONE
ORANGE TO PURPLISH
CONE
OXIDIZING ZONE
FLAME AS SEEN WITHOUT WELDER'S GOGGLES
FLAME AS SEEN WITH WELDER'S GOGGLES
OXIDIZING FLAME
INTENSE WHITE CONE
WHITE OR COLORLESS
ORANGE TO BLUISH
CONE
REDUCING ZONE
FLAME AS SEEN WITHOUT WELDER'S GOGGLES
FLAME AS SEEN WITH WELDER'S GOGGLES
REDUCING FLAME

Fig 3-5. Oxyacetylene flames.

h. Oxyacetylene welding precautions. When you are involved in any oxyacetylene welding operations there are a few precautions you should observe to produce a sound weld. Not only does skill in controlling the motion of the flame, the rod, and the molten pool of metal produce a good weld, but some of the steps listed below are necessary:

Use a neutral flame for welding most steels.

Use the tip size and volume of flame sufficient to reduce the metal to a molten state and permit complete fusion of the filler rod and the base metal.

Avoid excessive pressure of the gases as this gives a harsh flame and makes it difficult to control the melting metal.

Permit the pool of molten metal to progress evenly down the joint as the weld is being made.

Hold the tip of the inner cone (fig 3-5) slightly above the work and do not permit it to come into contact with the welding rod, the molten pool, or the base metal. Hold the flame so that the molten pool is protected from the atmosphere by the outer flame envelope (fig 3-5).

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. A method that will produce a weld without filler metal or pressure when light sheet metal is being welded is

   a. oxyacetylene welding. c. forge welding.
   b. brazing. d. resistance welding.

2. The reason acetylene gas can be confined in cylinders at 250 psi without becomming explosive is the

   a. cylinders are filled with absorbent material.
   b. acetylene is dissolved in acetone under pressure.
   c. cylinders are only filled 40%.
   d. cylinders are equipped with safety plugs.

3. The statement which best describes oxygen is that

   a. it is always combined with other gases.
   b. it is much lighter than air.
   c. it supports combustion by combining with other gases.
   d. it passes a distinctive odor.

4. The high pressure gauge on the inlet side of the oxygen regulator is graduated from ____________ to ____________ psi.

   a. 0 - 1,000 c. 0 - 3,000
   b. 0 - 2,500 d. 0 - 5,000

5. A cylinder of gas that bares no marking except for the orange color of the cylinder contains a (an) ______________ gas.

   a. refrigerant c. oxidizing
   b. fuel d. oxygen

6. The high pressure gauge on the inlet side of the acetylene regulator is graduated from

   a. 0 to 220 cu. ft. c. 0 to 1,000 psi.
   b. 0 to 200 cu. ft. d. 0 to 2,000 psi.

7. The maximum number of turns that the acetylene tank valve should be open is

   a. 1. c. 2.
   b. 1 1/2. d. full open.

8. A welder using a 2-step regulator has the advantage of

   a. reduced total pressure. c. less pressure adjustments.
   b. safety. d. increased working pressure.

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9. The best means of identifying an oxygen hose from an acetylene hose is

   a. by the left-hand threads on the brass coupling.
   b. that it has the word "oxo" stamped on it.
   c. that an oxygen hose is red.
   d. that an oxygen hose is green.

10. The color of an acetylene bottle is

   a. yellow.
   b. orange.
   c. green.
   d. gray.

11. The color of an oxygen bottle is

   a. yellow.
   b. orange.
   c. green.
   d. gray.

Work Unit 3-2. OXYACETYLENE BRAZING

IDENTIFY THE TWO ALLOYS USED IN BRAZING.

a. Brazing with silver-based alloys. Brazing with silver-based alloys (commonly known as silver soldering) is a process where bonding is produced by heating the metal to a suitable temperature above 800°F, and using a silver alloy filler metal that has a melting point below that of the base metal. Joints designed to employ capillary attraction (the principle by which an ink blotter blots up ink) are best suited for silver soldering because of high strength obtained. Because of the low flowing temperature of the silver solder, less heat is required, thus offering a number of advantages. The low temperature used in silver soldering avoids the heating of the parts to be soldered to a point where the physical properties of the metals will be impaired by distortion, warpage, loss of ductility, etc. Silver alloy filler metals can be used on virtually all ferrous and nonferrous metals with the exceptions of aluminum, magnesium, and metals having a melting point below that of the solder itself. Practically any metal that can be heated above 1,200°F can be satisfactorily joined. The strength of a silver-soldered joint depends on the joint fit-up or the distance between the two metals being soldered, and the quality of the bond between the filler metal and the base materials. The heat reguired on the base metal opens the pores, so to speak, on the base metal and allows the solder to penetrate these pores along the surface of the two metals. This causes a physical bond between the filler and the base metal. It is this bond that produces the high strength of a soldered joint. Parts that are silver-soldered should not be used where they are to be subjected to temperatures that exceed 500°F. The silver solder bond becomes progressively weaker as the temperature increases. Silver solder can be obtained in grades with a silver content ranging from 10% to 80% and having a melting point from 1,160° to 1,600°F. It comes in strip, wire, rod, and granulated form. The strip form is generally used in fixed setups where the solder can be placed before heat is applied. The rod and wire forms are mainly used for joints where it is preferrable to apply the solder by hand. The type of joint used is an important factor, as the preparation, fit-up, and results obtained differ from those obtained in fusion welding. Silver solder should not be used as a filler material. These alloys flow in narrow openings, and the strongest joints result from using small clearances between joint surfaces. The recommended joint clearance at soldering temperature is between 0.002 and 0.005 inch. Basically there are two types of joints used in silver soldering, the lap joint and the square edge butt joint (figs 2-6 and 2-10). The lap joint is the most common, as it employs capillary attraction and is the strongest. To insure quality and a good sound soldered joint, it is important that a clean, oxide-free (scale-free) surface be used. All oil, grease, rust, dirt, and oxides must be removed from the base metal and the filler rod to insure complete capillary attraction throughout the joint. Any coating over the parent (base) metal must also be removed, for example paint and lacquer, as well as plating materials, such as chrome, cadmium, etc. It is recommended that soldering be done as soon as possible after cleaning off the base metal and filler metal.

(1) Fluxes. A flux is required when silver soldering to effect a good, strong, uniform joint. A good flux should accomplish a number of objectives. It should react with surface films, such as oxides, reducing them and enabling the metal to present clean surfaces to the molten silver alloy. It should form a protective film during the soldering and thereby prevent reoxidation at the elevated temperatures required for the soldering, and it should allow the silver alloys to flow freely. The use of a flux does not avoid the need for cleaning the parts before soldering. The purposes of the flux is to supplement the initial cleaning procedures by dissolving, restraining, or otherwise rendering ineffective those products that would otherwise lessen the quality of the joint or prevent bonding. Flux comes in a variety of forms, such as powder, paste, liquid, and solid coating for application to the silver alloy filler metal. Fluxes must be removed after soldering is completed, since trapped fluxes can weaken and corrode the joint.

(2) Heating joints. Since oxyacetylene torches provide the highest flame temperatures, the torch should be large enough to allow the use of a neutral or slightly carburizing flame. The tip size depends on the thickness of the base metal. Don't let the inner cone or carburizing flame touch the metal, as this will cause the filler metal to be sluggish at the flow point and the flux may be burned. The torch should be kept in motion all the time, as holding it in one place too long can easily overheat the base metal and flux. If a part is overheated, capillary action is hindered and the parts must be recleaned and all oxides removed. Low heat and cleanliness are the secrets in silver soldering. On a large scale you must preheat the metal well away from the joint, especially when soldering metals which heat rapidly throughout. Care must be taken when soldering metals of unequal thicknesses or unequal heat conductivity, because it is necessary that each reach the soldering temperature at the same time. The indication of complete bonding through the joint is forming a small fillet at the face of the joint.

b. Brazing with copper-based alloys. A process that utilizes copper-base filler alloys, but employs joint designs similar to those used in oxyacetylene and arc welding, is known as braze welding. The fact the brazing welds without melting the base metals greatly simplifies the welding procedure, and since it requires less heat, the speed is increased. Consequently less time and less gas are required to do a given job. Because of the less heat required for brazing, preheating is easier. All that is needed is local preheating (800°-900°F). Naturally, expansion and contraction are greatly reduced, thus making it possible to repair broken castings and other parts in place, saving time and the expanse of dismantling and reassembling. Brazing is widely used not only for welding broken castings, but also in the rebuilding of missing or worn parts such as gear teeth, valve disks, and seats. Pistons, rotary valves, guides, and other sliding surfaces on pumps, engines, and machinery parts may be successfully repaired and rebuilt with braze welding. Braze welding should not be used where it would be subjected to temperatures in excess of 650°F. The best filler metal for brazing has about 60% copper and 40% zinc content. This ratio will produce the best combination of high tensile strength and ductility. The alloy possesses considerable strength when hot and solidifies quicker than any of the other copper-zinc combinations. This is an additional advantage, since a quick-freezing alloy has much better weldability than one which remains mushy over a wide temperature range. Strong braze-welded joints depend on proper preparation, the correct technique, the strength of the filler alloy, and the bonding of filler alloy and the base metal. Adequate preparation, which includes thorough cleaning, is essential. Removal of all oxides, paint, and plating substances from the joint surfaces is necessary. The metal on the underside as well as on the top of the joint must be bright and clean. If the parts to be joined are less than 1/4 inch thick, it is not necessary to "V" the edges, but if the base metal cross section is over 1/4 inch, the edges must be beveled (cut at an angle) to about a 90°V. The cleaning of the joint surfaces should extend back from the joint about 1/2 inch to permit easy tinning. Without timing, a satisfactory braze-welded joint is impossible. Once you have the parts properly cleaned, the next step is to aline the parts by the use of clamps or tack welding. When braze-welding a casting, you must heat it along the line of the weld. The temperature of the welding heat will set up strain, due to expansion and contraction, unless the casting is preheated. In small castings, up to about 100 pounds, the heat from the torch is sufficient to preheat the entire casting. Besides providing for the relief of stresses, preheating speeds up the brazing operation and requires the use of less oxygen and acetylene.

(1) Fluxing. The use of flux is essential when braze-welding with oxyacetylene. It is needed for two reasons: to remove oxides that form ahead of the welding zone due to oxygen in the air, and to dissolve the oxides formed in the brazing operations. Use plenty of flux but add it carefully. The puddle should not be made mirror clear, but should be slightly clouded with oxide. Where the welding is rapid, it is best to coat the entire filler rod with flux. If the operation is slow, as with heavy castings, you can dip the hot end of the filler rod into the flux and add to the puddle as required.

(2) Tinning. After you have properly prepared, cleaned, alined, fluxed, and preheated the parts, if necessary, you tack-weld them together. Then you heat the metal with a torch at the point where the weld is to start, using a slightly oxidizing flame. This aids in serving a better bond between the filler and base metals and assists in keeping a slight film of oxide over the puddle. Play the torch, using a circular motion, over the part to be heated. As the base metal gets hot, test its temperature with a drop of metal from the welding rod. When the base metal temperature is right, the molten filler metal spreads evenly over the surface, producing a tinning coat on the base metal. You can tin the base metal only when conditions are right. If the base metal is too cold, the filler metal will form little balls like drops of water on a hot stove. Tinning is the most important step in the braze-welding operation. The free-flowing film of alloy forms the intimacy of contact necessary for the bonding of base metal and filler metal. When the immediate area under the flame is tinned, additional metal is added as necessary to fill the V. Tinning must at all times continuously precede filling the joint. As the tinning action progresses, you continue to feed the bronze welding rod into the molten pool to build the weld to the desired size. The puddle should be small in size, but increase as it is moved forward until it completely fills the V and a full-sized braze weld is made. Good braze welding combines into one continuous action and tinning and the building up of the weld. The inner flame cone is kept from 1/8 to 1/4 inch away from the surface of the metal. Usually the flame is pointed ahead of the completed weld at about a 45° angle, with the puddle under and slightly behind the flame. The proper rate of braze welding is controlled by the rate of tinning; never flow the rod faster than the tinning action. After you have finished the welding operation, you should play the torch over the weld and on either side of the weld for several inches, continuing this until all parts have been brought to an even heat. The parts should be allowed to cool slowly and should be protected from drafts and cold air. Never stress (try to bend or use in any way) a braze-welded joint until it has cooled completely.

c. Hard-surfacing. Surfacing is a process in which a layer of special ferrous or nonferrous alloy is welded to the surface of a new or used part to increase resistance to impact, corrosion, abrasion, erosion, or to obtain other properties. Surfacing is also used to build up undersized or worn parts. Hard-surfacing alloys are of many types, each one best adapted to combat the destructive forces in a given operation. No single hard-surfacing material is satisfactory for use on all occasions. For the purpose of simplification, these alloys are generally classified into five broad groups:

(1) Group 1: Consists principally of an iron base with less than 20% of alloying elements. The alloying elements used are mainly chromium, tungsten, manganese, silicon, and carbon. Although not as hard, they have greater toughness and shock than other hard-surfacing alloys. They are used to build a badly worn surface before applying a better grade of hard-surfacing alloy.

(2) Group 2: consists of iron-base alloys having 50% to 80% iron and more than 20% alloying elements, mainly chromium, tungsten, manganese, silicon, and carbon. Small precentages of cobalt and nickel are sometimes added. These alloys are used for hard, wear-resisting surfaces.

(3) Group 3: Consists of nonferrous alloys of cobalt, chromium, and tungsten, as well as other nonferrous hard-surfacing metals. They are available in different grades. All are highly resistnat to wear, but possess a toughness and range in strength that permit use for a wide variety of purposes. They resist heat corrosion and errosion. These materials are used extensively for fabricating valve seats in internal-combustion engines.

(4) Group 4: Consists of alloys of so-called carbide materials or diamond substitutes which are the hardest and most wear-resistant of all hard-facing materials. Some of these alloys contain 20% to 90% tungsten carbide. The remainder of their content is cobalt, nickel, iron, or similar metals. They give strength, toughness, heat resistance, and impact strength to the tungsten carbide.

(5) Group 5: Consists of alloys of crushed tungsten carbides of various sizes. These may be fused to strips of mild or low-alloy steel embedded in hard-surfacing material, or they may be packed in lengths, which may be applied to the wearing surface as welding rod.

In general, the hard-surfacing alloys or materials can be applied by either the oxyacetylene or the electric-arc methods of welding. Alloys in groups 1 and 2 are welded to the base metal or surface. Care should be taken to avoid puddling or mixing the base metal with the hard-surfacing material, as this will lower the wear-resistance properties of the surfacing coating. Those in group 3 are usually "sweated" to the surface, as in brazing, without melting the base metal. None of the base metal penetrates into the hard-surface layer to reduce its resistance to abrasion or wear. The materials in groups 4 and 5 are not melted, but are bonded by or embedded in mild or low-alloy steels or hard-surfacing materials, which in turn are welded to the base metal. Hard-surfacing alloys are supplied with an oxyacetylene flame and rods of suitable design when it is desired to spread the material or metal over the surface in thin layers. The electric-arc method is used when the surface wear is severe and a somewhat irregular surface of the deposited metal is satisfactory. Before applying hard-surfacing materials, the welder should determine the conditions under which the particular piece will operate and the type of wear expected. There may be present any one or more of the following factors which will increase wear: shock and impact, heat, corrosion, sliding or rolling friction, or abrasion. In rock-crushing and similar equipment where resistance to shock and impact is more important and hardness only secondary, the hard-facing alloy of groups 1 and 2 are used. In valves designed for handling gas, oil, acids, high temperatures, and high-pressure steam, resistance to heat, corrosion and erosion is provided by the group 3 alloys. Group 4 and 5 alloys, being very tough and extremely hard, are used where the wearing surfaces come into contact with earth, sand, gravel, as on blades of scrapers, grading equipment, rotary drill bits, teeth on shovel buckets, and similar applications where a high resistance to abrasion is desired. In most cases, worn sections are rebuilt with hard-surfacing deposits ranging from 1/16 to 1/4 in. thick, depending on the specific application. Where it is necessary to rebuild the parts in excess of 1/4 in., the parts are built-up with group 1 type alloys to form 1/16 to 1/4 in. of the finished size. The final hard-surface deposit, consisting of groups 2 and 3, is added with some excess to permit grinding to the final desired dimensions. When the harder and more brittle groups 4 and 5 are applied, either as a final hard facing, or a single layer, the shape of the deposit should be carefully controlled. This is important in order that the shock or impact loads may be transmitted through the hard-surfacing metal into the tougher base metal. Corners, sharp edges, or built-up sections, when not backed up by tough base metal, will chip or break off in service.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The most common joint used in silver soldering is __________ joint.

   a. lap
   b. single-V
   c. single-J
   d. single-bevel tee

2. The recommended joint clearance at soldering temperature is between

   a. 0.002 and 0.005 in.
   b. 0.02 and 0.05 in.
   c. 0.005 and 0.008 in.
   d. 0.008 and 0.012 in.

3. When brazing a cast-iron part, the base metal is at welding temperature when

   a. the part appears yellow.
   b. a tinning coat is produced.
   c. the flux appears like water on a greasy surface.
   d. the base becomes soft.

4. To obtain high resistance to abrasion, you would hard-surface the teeth in a power shovel bucket with group __________ hard-surfacing materials.

   a. 1
   b. 2
   c. 3
   d. 4

5. The two alloys used in brazing are __________ based alloys.

   a. lead and copper
   b. copper and silver
   c. aluminum and lead
   d. magnesium and silver

Work Unit 3-3. OXYACETYLENE WELDING

DESCRIBE THE TWO WELDING TECHNIQUES.

a. Welding techniques. Oxyacetylene welding may be accomplished by either of two techniques, forehand or backhand. Each has special advantages and the one used depends on the position of the rod and torch during welding, not the direction of welding. As far as direction is concerned, you can weld from left to right or from right to left. The best method to use depends on the type of joint, its position, and the necessity for controlling the heat on the parts to be welded.

(1) Forehand (fig 3-6). This is the oldest method of welding, and the one used most. In forehand welding, the rod is kept ahead of the tip in the direction in which the weld is being made. Point the flame in the direction of the welding and hold the tip at an angle of about 60° to the plates. The position of the flame preheats the edges just ahead of the molten puddle. By moving the tip and the welding rod back and forth in opposite, semicircle paths, you balance the heat to melt the end of the rod and the sidewalls of the joint into a uniformly distributed molten puddle. As the flame passes the rod, it melts a short length and adds it to the puddle. The motion of the torch distributes the molten metal to both edges of the joint and to the puddle. This method is used in all positions for welding sheets and plates up to 1/8 inch thick, because it permits better control of a small puddle which in turn results in a smoother weld.

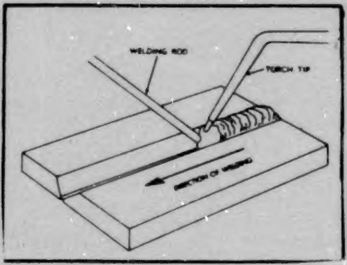


Fig 3-6. Forehand welding.

(2) Backhand (fig 3-7). In this method the torch tip precedes the rod in the direction of welding, and the flame is pointed back at the molten puddle and the rod. The end of the rod is placed between the torch tip and the molten puddle, and the welding tip should make an angle of about 60° with the plates of joint being welded. Less motion is required with the torch and tip than it is in the forehand method. If you use a straight welding rod, rotate it so that the end will roll from side to side and melt evenly. You may also bend the rod and, when welding, move the rod and torch back and forth at a rather rapid rate. To make a large weld, you should move the rod so as to complete circles in the molten puddle. Move the torch back and forth across the weld while advancing it slowly and uniformly in the direction of the welding. You will find the backhand method easier for welding material thicker than 1/8 inch. You can use a narrower V at the joint than is possible in forehand welding. It doesn't take as much welding rod or puddling, and it is possible to increase welding speeds and obtain better control and more complete fusion at the root of the weld by the use of the backhand method on heavier materials.

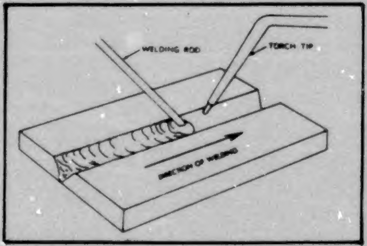


Fig 3-7. Backhand welding.

b. Welding ferrous metals. Low-carbon steel, low-alloy steel, cast steel, and wrought iron are easily welded with the oxacetylene flame. A flux is not necessary with these metals, but it is essential that the molten puddle of weld metal be enclosed at all times by the envelope of flame during the welding process. If the molten metal is allowed to contact the air, it will oxidize rapidly. Excessive heat should be avoided, as too large a flame overheats the metal, and causes it to spark and burn. Either the forehand or backhand welding technique may be used. The torch flame should be neutral or slightly reduced; do not use an oxidizing flame. Manipulate the torch and rod so that the tip of the oxyacetylene cone is about 1/16 to 1/8 in. from the surface of the metal. Melt the end of the filler rod in the puddle, not with the flame. The welding of low-carbon steels and cast steels poses no problems other than the selection of the rod. Low-alloy steels usually require prewelding and postwelding heat-treatment to relieve stresses developed during welding and to produce the required physical properties. As the carbon content increases, welding becomes more difficult. Steels having a carbon content within the range of 0.30% to 0.50% are welded with a slightly reducing flame and require postwelding heat treatment to develop the best physical properties. Otherwise, the technique is the same as for welding mild steel. High-carbon and tool steel require a slightly different technique. Slow preheating with the part protected from cool drafts to about 1,000°F is necessary. No flux is needed, but the weld should be completed as soon as possible with a carburizing flame. Filler metal should be added a drop at a time just where it is needed. To avoid overheating, use a smaller flame and lower gas pressure than that used for mild-steel. High-carbon steels must be heat-treated after welding to develop the physical properties required. The procedure for welding wrought iron is the same as that for low-carbon steels, but several points should be kept in mind. Wrought iron, as you may recall, contains an iron silicate slag incorporated during its manufacture. This slag will give the surface of the molten puddle a greasy appearance, so do not confuse this appearance with actual fusion, but continue to apply heat until the sidewalls of the weld joint break down into the puddle. Best results can be obtained when the filler metal (usually mild steel) and base metal are mixed in the molten puddle with a minimum of agitation. Usually a single V-joint with a 60° to 80° groove angle and a 1/16-inch root opening is suitable for metal thicknesses requiring an edge preparation.

c. Welding nonferrous metal. While brazing and braze welding are used more extensively than oxyacetylene welding to make joints in nonferrous metals, the fusion process is frequently applied. In general, the joint designs for welding nonferrous metals are the same as those used for welding steel. Adequate cleaning of the weld parts, the use of flux and filler metal are necessary, but with an oxidizing flame none is required as the oxide formed on the surface will protect the molten metal. Because of the high thermal conductivity of copper, preheating to 500° to 800°F is necessary to bring the joint up to welding temperature. For the same reason, use a torch tip one or two sizes larger than that used for welding steel of the same thickness. After welding is completed, cool the part slowly. Copper-zinc alloys (brasses) are welded with the same technique except that a silicon copper rod is used. A 200° to 300°F preheat is satisfactory for brass. A slightly different technique is used for copper-silicon alloy than that used for copper and copper-zinc. Using a flux containing a high boric acid content and a slightly oxidizing flame, maintain a small molten pool of metal and add filler metal having the same composition as the base metal. As the welding progresses, dip the rod beneath the film covering the puddle. A small puddle is desirable to permit the weld to solidify rapidly. To weld the copper-nickel alloys, use a rod having a composition the same as the base metal and a flux designed for monel. With a brush, apply the flux in the form of a thin paste to all parts of the joint and to the rod. Use a slightly reducing flame adjustment, with the tip of the inner cone just touching the base metal. Keep the end of the rod within the envelope of the flame, adding to the molten pool without agitating the pool. Limit the welding of the base metal to no more than is necessary to insure a good fusion. Run the weld the complete length of the joint without stopping. After the weld is completed, cool it slowly and then remove the remaining traces of the flux with warm water. For the welding of nickel or high-nickel allows, a good cleaning of the weld joint is essential. Straight nickel is welded without a flux, but high-nickel alloy requires a special boron- and borax-free flux applied as a thin paste with a small brush. Both sides of the seam, top and bottom, and the welding rod have to be coated with the flux paste. Make the weld with a very slight reducing flame, keeping the flame soft, and using a tip about one size larger than that used for steel of the same thickness. Keep the tip of the cone in contact with the molten pool and the welding rod within the protective flame at all times. After the weld is completed, postheat the part, and allow it to cool slowly; then remove the flux with warm water. Sucessful welding of these, or for that matter any metals, requires a great deal of skill that can only come from practice.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. In welding with the forehand or the backhand method, the angle between the torch tip and the work piece should be approximately

a. 15°.	c. 60°.
b. 30°.	d. 90°.

2. In welding low carbon steel the torch should be adjusted

   a. to use equal volumes of acetylene and oxygen.
   b. to a slightly oxidizing flame.
   c. until the flame makes a slight rushing sound.
   d. to a neutral or slightly reducing flame.

3. The tip size for welding non-ferrous metals should be ________ larger than required for welding steel of the same size.

a. 1 - 2 sizes	c. 4 sizes
b. 3 sizes	d. 5 sizes

4. Describe the forehand technique of welding.

   ____
   ____
   ____

5. Describe the backhand technique of welding.

   ____
   ____
   ____

Work Unit 3-4. CUTTING METALS WITH OXACETYLENE

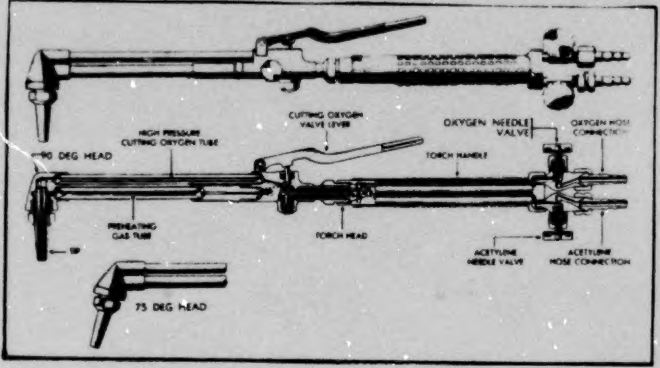
IDENTIFY THE PROCEDURES FOR CUTTING METAL WITH OXACETYLENE.

IDENTIFY THE FOUR TECHNIQUES USED IN CUTTING METAL.

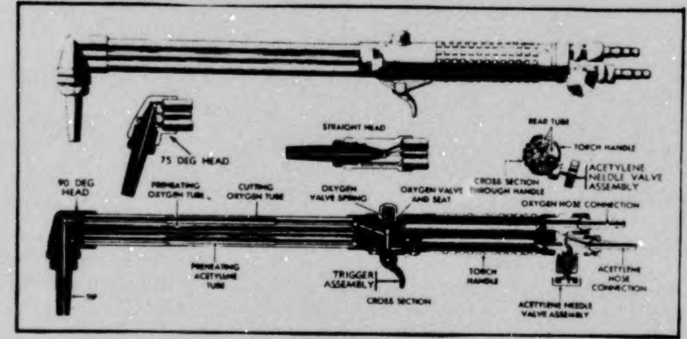
IDENTIFY TWO GAS-WELDING SAFETY PRACTICES.

a. It may be hard at first to realize that you can use the oxyacetylene process for both welding and cutting, one being the exact opposite of the other. But the principle that enables you to cut through inches of tough steel in a short time is not too hard to understand. The principle is that steel, when preheated to the kindling temperature range (1,400° to 1,600°F), burns very rapidly in an atmosphere of pure oxygen. So when a jet of pure oxygen is directed on red-hot steel, a chemical reaction takes place. This reaction forms iron oxide and gives off a lot of heat. This heat is sufficient to melt the iron oxide and some free iron which runs off as molten slag, exposing more iron to the jet. It might be said that the burning or oxidizing process is an extremely rapid rusting, the rust being formed under heat. Only the metal that is in direct path of the oxygen jet is affected. When the steel is cut, a narrow slit known as a kerf is found. The steel or iron that is removed from the kerf is only about 60% to 70% oxidized by the oxygen; the remainder is blown out the opposite side as metallic iron. The walls of the kerf that are formed by this cutting action are fairly smooth and parallel to each other. Under skilled workmanship and controlled torches, very accurate cuts can be made, and the cutting torch becomes an indispensable tool in the shop.

(1) Cutting equipment. In general, the oxyacetylene cutting equipment is the same as the oxyacetylene welding equipment, with the exception of the torch. The cutting torch mixes oxygen and acetylene in definite proportions, burning the mixture in preheating flames which are allowed to heat the work, and directing a jet of pure oxygen at high pressures to sever the metal along the line of the cut. The cutting torch (fig 3-8A) consists of a handle, connecting tubes, and a head. The handle is equipped with the oxygen and acetylene hose connections at the rear end. A needle valve in the acetylene inlet connection controls the supply. The oxygen furnished to the preheating flames is regulated by a preheat valve on the side of the handle. A high-pressure oxygen valve, with its spring and seat operated by a trigger or lever, controls the cutting oxygen. The preheating acetylene and oxygen are mixed in the head of the cutting torch. There is also a cutting attachment which fits the head of the standard welding torch (3-8B). This attachment is very useful for intermittent cutting and welding of lighter sections. With this type of attachment, the preheating gases are mixed in the torch head and are controlled by the oxygen acetylene needle valves. The high-pressure cutting oxygen is controlled by the oxygen valve lever located on the cutting attachment. The use of this attachment is not recommended for sustained heavy cutting operations. Such work should be done with heavy-duty cutting torches.


HIGH PRESSURE CUTTING OXYGEN TUBE
CUTTING OXYGEN VALVE LEVER
OXYGEN NEEDLE VALVE
OXYGEN HOSE CONNECTION
90 DEG HEAD
TORCH HANDLE
PREHEATING GAS TUBE
TORCH HEAD
TIP
ACETYLENE NEEDLE VALVE
ACETYLENE HOSE CONNECTION
75 DEG HEAD

A. Cutting torch.


STRAIGHT HEAD
REAR TUBE
TORCH HANDLE
75 DEG HEAD
ACETYLENE NEEDLE VALVE ASSEMBLY
CROSS SECTION THROUGH HANDLE
90 DEG HEAD
PREHEATING OXYGEN TUBE
CUTTING OXYGEN TUBE
OXYGEN VALVE SPRING
OXYGEN VALVE AND SEAT
OXYGEN HOSE CONNECTION
PREHEATING ACETYLENE TUBE
TRIGGER ASSEMBLY
CROSS SECTION
TORCH HANDLE
ACETYLENE HOSE CONNECTION
ACETYLENE NEEDLE VALVE ASSEMBLY
TIP

B. Cutting attachment for welding torch.

Fig 3-8. Cutting torch and attachment.

Whether you use a cutting torch or cutting attachment, you will notice that the tips are made the same way. The cutting tip is made with a number of orifices as shown in figure 3-9. The jet of oxygen that actually does the cutting is emitted from the center hole, and the smaller holes surrounding the center hole are for oxyacetylene preheat flames. The tip size is usually marked so that the larger the number is, the bigger the tip is. The taper-sealed, separable cutting tip is held in the cutting torch head by the tip nut. Cutting tips are supplied in various length and shapes as well as sizes. Bent tips are used under various conditions such as gouging, scarfing, rivet cutting, and flame machining. When using the cutting torch, don't hold the tip too close to the metal when starting a cut, as the blowing action of the oxygen blast tends to bounce the molten metal and slag from the cutback to the torch tip. When this happens, the tip holes must be cleaned with the proper-size tip cleaners. Don't improvise. Use the proper-size tip cleaner and push it into the clogged orifices; don't rotate it. If the end of the tip becomes rough and pitted and the holes become oversize (bellmouthed), you can recondition it by placing a piece of emery cloth, grit side

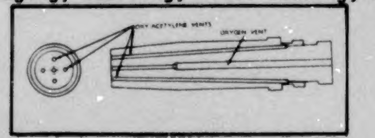

OXY-ACETYLENE VENTS
OXYGEN VENT

Fig 3-9. Cutting tip construction.

up, on a flat surface, and holding the tip perpendicular to the emery cloth, rubbing it back and forth just enough to true the surface and bring the orifices back to the original diameter. After cleaning the tip, test it. If the flames are short, the gas passages are partially blocked and if the preheating flames snap out when the valves are shut, the holes are still bellmouthed and the surface needs more work. If the tip seat is dirty and scaly, heat it to a dull red and quench in water. This loosens the scale enough so that it can be removed easily with a cloth. Tip style and size are governed by the operation being performed and thickness of the material being cut. Cutting-tip numbers, gas pressures, and hand-cutting speeds used for cutting mild steel up to 12 inches thick are shown in figure 3-10.

Plate thickness (in.)	Cutting tip (1) (size number)	Oxygen pressure (psi)	Acetylene (psi)	Hand-cutting speed (in. per min)
1/4	0	30	3	16 to 18
3/8	1	30	3	14.5 to 16.5
1/2	1	40	3	12 to 14.5
3/4	2	40	3	12 to 14.5
1	2	50	3	8.5 to 11.5
1 1/2	3	45	3	6.0 to 7.5
2	4	50	3	5.5 to 7.0
3	5	45	4	5.0 to 6.5
4	5	60	4	4.0 to 5.0
5	6	50	5	3.5 to 4.5
6	6	55	5	3.0 to 4.0
8	7	60	6	2.5 to 3.5
10	7	70	6	2.0 to 3.0
12	8	70	6	1.5 to 2.0

(1) Various manufacturers do not adhere to the numbering of tips as set forth in this table; therefore, some tips may carry different identification numbers.

Fig 3-10. Oxyacetylene cutting information.

(2) Operating cutting equipment. Attach the proper tip to your cutting torch for the thickness of the metal to be cut and adjust the oxygen and acetylene pressures. For cutting medium steels, adjust the preheat flames to neutral. Hold the torch perpendicular to the work, with the inner cones about 1/16 in above the end of the line to be cut. Hold the torch in this position until the spot beneath it has been raised to bright red heat; then open the oxygen valve slowly but steadily. If the cut has been started properly, you should see a shower of sparks fall from the opposite side of the work, indicating the cut is going through the metal. Move your torch forward along the line fast enough for the cut to continue to completely penetrate the work. If you have made the cut properly you will get a clean, narrow kerf which looks like one you might get by sawing. You will have to move the torch along at just the right speed, not too fast and not too slow. If your cutting speed is too slow, the preheat flame will melt the edges and may weld them back together. If you go too fast, the oxygen will not penetrate completely through the metal and you will have to stop and go back and start the procedure over again. Try to make a smooth cut. Anyone who can light the torch can cut steel after a fashion, but it takes a sharp metalworker to get a smooth cut. If it isn't perfect, check the following points:

Preheating flames. The cut will appear gouged at the bottom if the flames are too short. If the flames are too long, the top of the cut will be fused together.

Oxygen pressure. Too low an oxygen pressure will melt the top edges. If the pressure is too high, the cut will be rough and irregular.

Cutting speed. A too slow cutting speed will leave irregular drag lines (marks left on a cut edge). If cutting speed is too fast, the drag lines will be rough and form sweeping curves.

A good cut shows smooth, vertical, uniform marks which are continuous from top to bottom. If you have to start a cut from a portion of the metal other than the edge, preheat the spot to a bright red, tilt the torch at an angle of 45° from the perpendicular and slowly open the high-pressure valve and as the torch starts to cut, start righting it back to a perpendicular position until it is in a 90° position. Move it forward and continue to make your cut. This eliminates the possibilities of blowing the slag back on your cutting tip and clogging the holes.

(a) Cutting bevels (fig 3-11). You will frequently have to cut bevels to form joints for welding. To make a bevel cut of 45° in 1-inch steel, the flame must actually cut through 1.4 in of metal. Consider this when you are selecting the tip and adjusting the valves. You will have to use more pressure and less speed for a bevel cut than you would with a straight cut. Adjust the tip so that the preheating orifices are lined up for efficient preheating. A piece of 1-inch angle iron, clamped with the angle up, makes an excellent guide for beveling straight edges. Pull the torch along this guide as shown in figure 3-11.

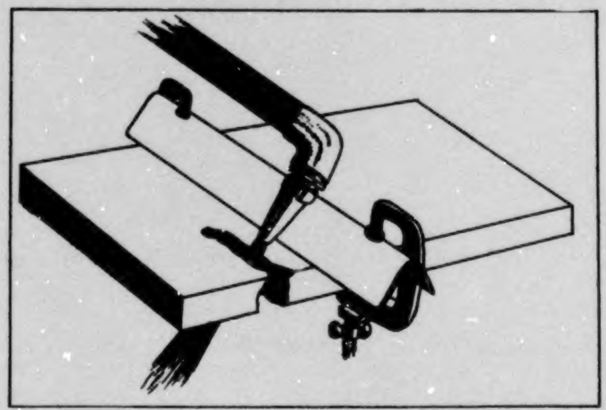


Fig 3-11. Cutting bevels.

(b) Pipe cutting (fig 3-12). When you are going to cut a section of pipe, keep the torch pointed toward the centerline of the pipe. Start the cut at the top and cut down one side. Then begin at the top and cut down the other side, finishing at the bottom as shown in figure 3-12. Pipe cutting with a torch requires a steady hand to get a good bevel, one that is smooth and true. Don't try to cut and bevel a heavy section of pipe in one trip. Cut the tip off square and then bevel it. This makes a cleaner and neater job. Check the alinement of your torch tip preheating orifices before you start your cutting. Arrange these orifices in line with your cut.

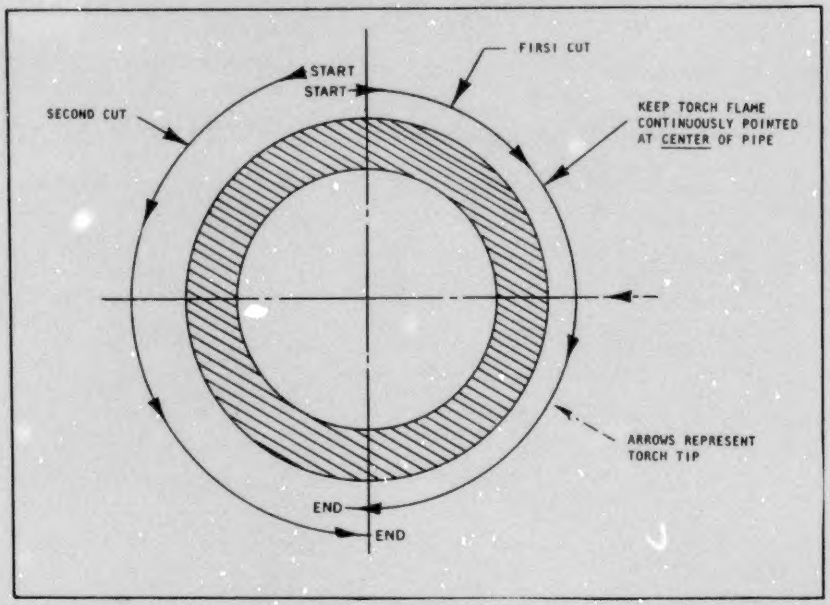

FIRST CUT
START
START
SECOND CUT
KEEP TORCH FLAME CONTINUOUSLY POINTED AT CENTER OF PIPE
ARROWS REPRESENT TORCH TIP
END
END

Fig 3-12. Cutting pipe with oxyacetylene.

(c) Piercing holes (fig 3-13). Your cutting torch is also a valuable tool for piercing holes in steel plate. Support the plates on firebricks or other means so that the flame will not hit anything else when it burns through. Hold the torch over the hole location with the tips of the inner cone of the preheating flames about 1/4 in above the surface of the plate. Continue to hold the torch until a small round spot has been heated to a cherry red. Open the high-pressure oxygen valve gradually and at the same time slightly raise the nozzle away from the work to keep from blowing slag back into the cutting tip. As you start raising your torch and opening the oxygen valve, start rotating the torch with a spiral motion. This will cause the molten slag to be blown out of the hole. The hot slag may fly around so avoid putting your head directly over the cut. If you desire larger holes, outline the area in chalk and, using the above procedure, follow the chalk lines that have been drawn on the plate.

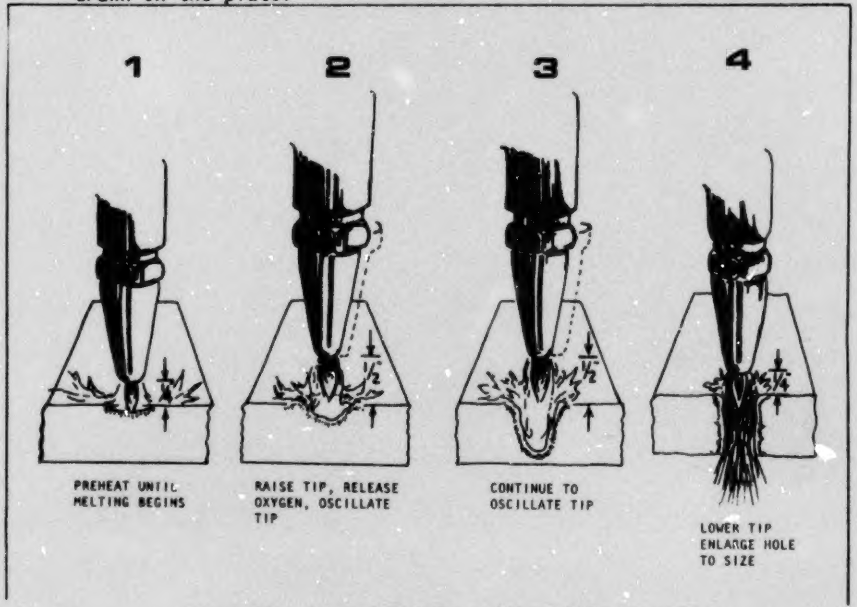

1
2
3
4
1/2
1/2
1/4
PREHEAT UNTIL MELTING BEGINS
RAISE TIP, RELEASE OXYGEN, OSCILLATE TIP
CONTINUE TO OSCILLATE TIP
LOWER TIP ENLARGE HOLE TO SIZE

Fig 3-13. Piercing holes with cutting torch.

(d) Rivet cutting. When you have a job of removing rivets, you will find that the cutting torch is another fast, expedient tool. Just use the preheating flames to bring the head of the rivet up to the proper temperature, then turn on the oxygen and wash the rivet head off. The remaining portion can then be punched out with a light hammer blow. The step-by-step procedure of removing rivets follows:

Use the tip size and pressures that you would use for 1-inch steel.

Heat a spot on the rivet head until it is bright red.

Move the tip to a position parallel with the surface of the plate and turn on the oxygen slowly.

Cut a slot in the rivet head like the screwdriver slot in a screw.

When the cut nears the plate, draw the tip back at least 1 1/2 inches. This is important.

When the slot is cut through to the plate, swing the tip through a small arc. This slices off half the rivet.

Then swing the tip in an arc in the other direction; this slices off the other half of the head.

After the slot is cut, you won't have to worry about preheating the rest of the rivet head to cutting temperature. Just before you get through the slot to the surface of the plate, draw your torch tip back 1 1/2 inches to allow the cutting oxygen to scatter slightly. This keeps the torch from breaking through the layer of scale that is always present between the rivet and the plate. It allows the rivet to be removed without damaging the surface of the plate. If you don't draw the tip away, you may cut through this scale and cut into the plate.

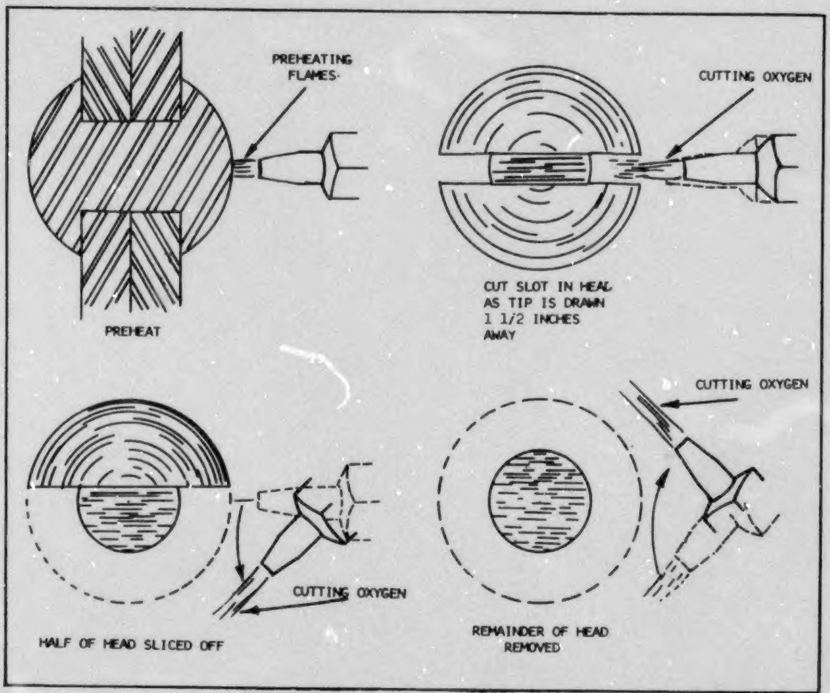

PREHEATING FLAMES
PREHEAT
CUTTING OXYGEN
CUT SLOT IN HEAD AS TIP IS DRAWN 1 1/2 INCHES AWAY
CUTTING OXYGEN
HALF OF HEAD SLICED OFF
CUTTING OXYGEN
REMAINDER OF HEAD REMOVED

Fig 3-14. Removing rivet.

(3) Cutting ferrous metals. Low-carbon steels (less than 0.35% carbon) are easily cut by the oxyacetylene procedure. They oxidize readily at the flame-cutting temperature and the oxide or slag formed during the cutting procedure melts at a temperature well below that of the metal itself. When the composition of the metal is such that the melting point of the oxide is as high or higher than that of the metal, the ease with which the metal can be cut decreases. The cut-ability of a ferrous metal decreases when the carbon present exceeds 0.35% or when allowing elements such as chromium, nickel, manganese, tungsten, vanadium, and molybdenum are included in the alloy. When metals of this type are to be cut, the standard procedure must be varied. As the cut-ability of a ferrous alloy decreases, it is necessary to use one or more of these techniques: additional preheat, a different flame adjustment, an oscillating torch manipulation or a special flux. For most flame-cutting operations, the oxyacetylene preheat flames are adjusted to a neutral flame adjustment. However, when cast iron is cut, a highly carburizing flame adjustment is necessary. The excess feather should be equal in length to the thickness of the cast iron. The excess acetylene helps to preheat the cast iron by igniting when it combines with the cutting oxygen in the kerf. Torch manipulation is an important part of the flame-cutting operation. For most applications, the torch is moved along the line of cut with a steady forward movement as shown in figure 3-15A. With metals like cast iron or stainless steel, the torch must be oscillated to work the oxide out of the kerf. In figure 3-15B the torch movement shown is recommended for light cast sections. The one at C is used for heavy cast-iron sections and the one at D is a forward and backward movement to flame-cut stainless steel. Frequently it is necessary to either preheat or postheat flame-cut metal. For higher than 0.35% carbon and alloy steel, you will have to take precautions to prevent the formation of a hard layer at the edges of the plates. This is more likely to be true when you are cutting so-called air-hardening steels, since a thin layer of metal at the cut edge is heated to a high temperature and rapidly quenched by the adjacent plate and the surrounding air. This hardens the edges of the metals, making them less ductile and more difficult to machine. Their lower ductility may even cause cracking under load. To avoid forming this hard layer around the edges, you should preheat the edges ahead of the cut. Preheating temperatures of from 500° to 600°F are sufficient to lower the rate of quench and should be used when cutting high-carbon and high-alloy steels. Cast iron is more difficult to cut than steel because it melts at a lower temperature than do its oxides. When cast iron melts, its oxides mix with it. This means that cast iron must be preheated to a much higher temperature than steel, and it also means that you will have to use an oxygen pressure of from 25% to 100% greater than you would for steel of the same thickness.

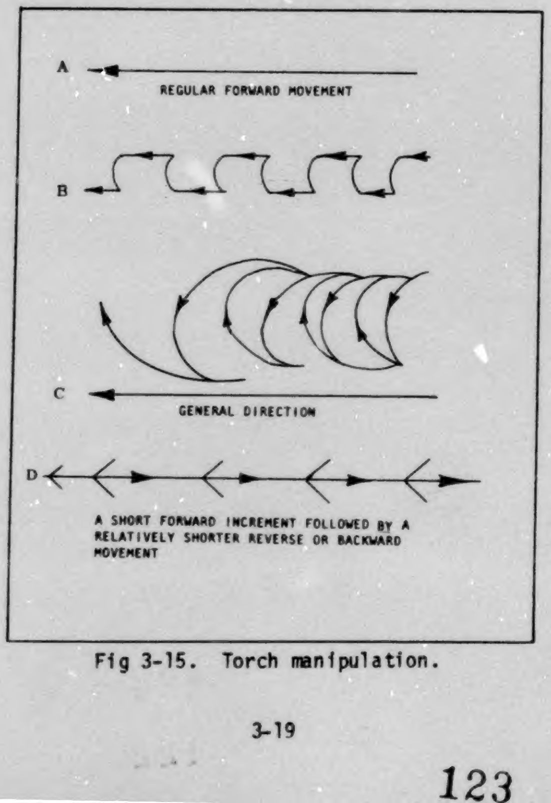

A
REGULAR FORWARD MOVEMENT
B
C
GENERAL DIRECTION
D
A SHORT FORWARD INCREMENT FOLLOWED BY A RELATIVELY SHORTER REVERSE OR BACKWARD MOVEMENT

Fig 3-15. Torch manipulation.

Start the cut with your torch tip forming an angle of 75° and 80° with the surface of the casting. As your cut progresses, gradually right the torch tip to an angle of 90° to avoid losing the cut. Move the torch forward just fast enough to sweep the edge of the cut. If you advance too deeply, progress of the cut will cease and black spots will develop under the cutting jet. From the beginning of the cut until it is finished, hold your torch tip 1 1/2 to 2 inches form the surface of the cast iron. Move the tip 1/2 to 3/4 inch in a semicircular weaving motion, as required, to clear the cut in heavy sections. Lighter sections won't require such wide movement to keep clear. The procedure for cutting cast iron can be further simplified by adding a mild steel rod to the kerf as cutting progresses. Assuming the tip size and the oxygen and acetylene working pressures for the thickness of material to be flame-cut have been properly selected from the manufacturer's charts, the following information will help you to determine whether the flame-cutting operation was properly performed. To produce a good cut with a square upper edge, the cutting torch must be held so that the inner cones of the preheat flames are about 1/16 inch from, and at right angles to, the surface of the metal. If the distance between the end of the preheat cones and the metal surface is greater that 1/16 inch, the metal will not be sufficiently preheated and the cut will be lost. If the preheat flames are too close, excessive preheat results and the upper edges will be rounded or fused together. The distance between the preheat flames and the surface of the metal determines, to a large extent, the appearance of cut. Another influencing factor is the speed of travel along the line of cut. If the cutting speed is too slow, drag lines or ridges of the cut will be straight up and down and the top edge may be rounded. If the speed of travel is too fast, there will be too much drag and the cut may be lost. Good cuts result when the position of the preheat flames and the speed of travel is such that oxidation takes place clear through the metal. Look down at the kerf while the cut progresses and observe the drag lines or the amount by which the cut curves backwards. Vary your speed accordingly. An important and often overlooked factor in flame cutting is the alinement of the torch tip preheating holes. When 90° cuts are made, these holes are alined as shown in figure 3-16. This illustration also compares good and bad cutting techniques. Check yours, and compare your result with the good cuts in the illustration.

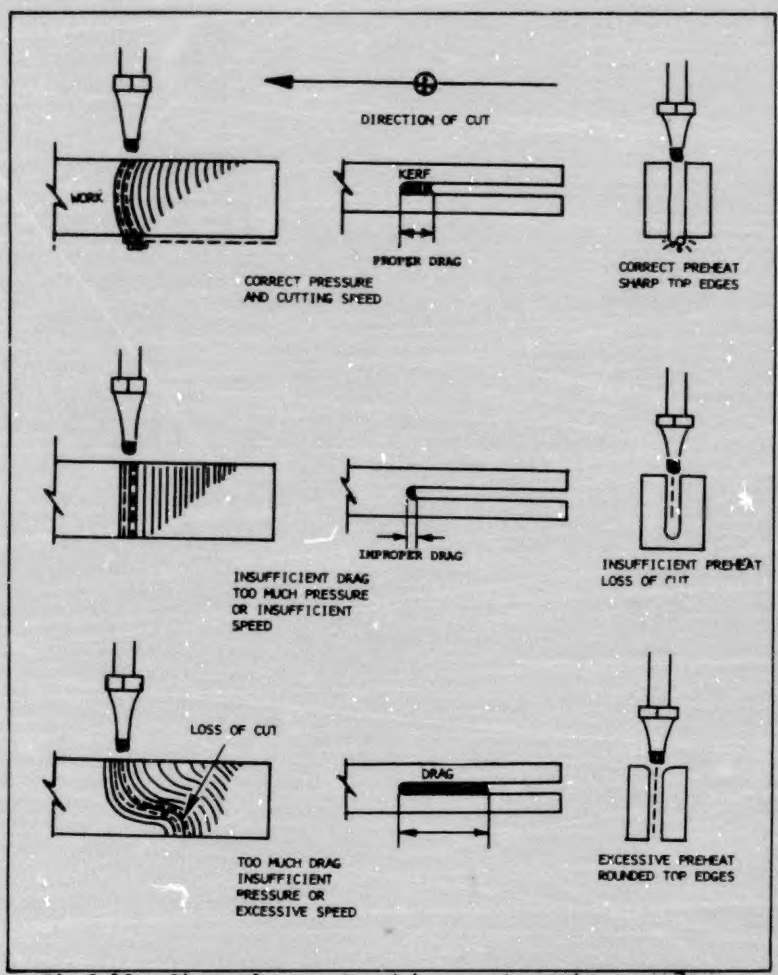

DIRECTION OF CUT
WORK
KERF
PROPER DRAG
CORRECT PRESSURE AND CUTTING SPEED
CORRECT PREHEAT SHARP TOP EDGES
IMPROPER DRAG
INSUFFICIENT DRAG TOO MUCH PRESSURE OR INSUFFICIENT SPEED
INSUFFICIENT PREHEAT LOSS OF CUT
LOSS OF CUT
DRAG
TOO MUCH DRAG INSUFFICIENT PRESSURE OR EXCESSIVE SPEED
EXCESSIVE PREHEAT ROUNDED TOP EDGES

Fig 3-16. Signs of correct and incorrect cutting procedures.

b. Gas-welding safety practices. Whether you are welding, torch brazing, flame cutting, or heating with oxyacetylene equipment, certain precautions must be observed to protect personnel and equipment.

(1) Oil and grease. Avoid the use of any lubricants in any form (oil or grease) on oxyacetylene equipment. Oil or grease in the presence of oxygen under pressure will ignite violently. Consequently, you must not let oil or grease come into contact with oxygen in any way while you handle cylinders, valves, regulators, hoses, or any other apparatus which uses oxygen under pressure. Do not permit a jet of oxygen to strike an oily surface or clothing. Oil or grease in contact with hose will deteriorate the rubber and lead to leaks.

(2) Lighting torches. Use friction lighters, stationary pilot flames, or some other sources of suitable ignition. Avoid the use of matches, cigarette lighters, etc., as a serious hand burn may result. Do not light a torch on hot metal, especially in a closed confined space. When lighting the torch, open the acetylene valve first, and ignite the gas with the oxygen valve closed. Do not alloy unburned acetylene to escape into a small or closed working area.

(3) Cylinders. Never use acetylene from cylinders without first reducing the pressure through a suitable pressure-reducing regulator. Acetylene working pressures in excess of 15 psi must be avoided. Oxygen cylinder pressure must be likewise reduced to a suitable working pressure. High pressure may burst the hose.

(4) Work space. Do not weld or cut material without first making certain that hot sparks or hot metal will not fall on the legs or feet of the operator, on the hoses, cylinders, or any flammable material lying around. When starting to work, always have a fire extinguisher within easy reach.

(5) Flashback and backfire. Unless the system is thoroughly purged of air and its connections are tight before the torch is ignited, the flame is likely to burn inside the torch instead of outside the tip. The difference between the two terms backfire and flashback is this: In a backfire, there is a momentary burning back of the flame into the torch tip; in a flashback, the flame burns in or beyond the mixing chamber of the torch. A backfire is characterized by a loud snap or pop as the flame goes out. A flashback on the other hand is usually accompanied by a hissing or squealing sound and, at the same time, the flame at the tip becomes smoky and sharp-pointed. When a flashback occurs, immediately shut off the acetylene valve. The occurence of the flashback indicates that something is radically wrong with the system. A backfire is less serious, and usually the flame can be relighted without difficulty. If backfiring continues whenever the torch is relighted, check for these causes: overheated tip, gas working pressure greater than that recommended, loose tip, or dirt on the torch-tip seat. These difficulties may be the cause of a flashback, except that they may be present to a greater degree. For example, the torch head may be cracked or distorted. In most cases, these malfunctions result from carelessness. They can be avoided by making certain that all connections in the system are tight and clean, torch valves are closed (not open or merely loosely closed) when the equipment is stowed, oxygen or acetylene working pressures used are those recommended for the torch employed, and the system is purged of air before use. Purging the system of air is especially necessary when new hoses and torch are used or when a new bottle of gas has been connected to the system.

(6) General precautions. Do not allow unauthorized presonnel to use oxyacetylene welding or cutting equipment. Do not conduct welding operations in buildings or structures that have wooden decks unless they are protected by sand, asbestos paper, or other fireproof material. Do not experiment with torches or regulators in any way. Do not use oxygen regulators with acetylene cylinders. Always use the proper tip or nozzle and always operate it at the proper pressure. Make certain that the torch is not burning when not in use and never hang the torch with its hoses on the regulators or cylinder valves. Keep a clear space between the cylinders and the work so that the valves can be reached in an emergency. Use cylinders in the order that they were received, and mark empty cylinders as such. Do not paint cylinders any color other than the original. Do not store oxygen cylinders with acetylene cylinders, and always store them in an upright position. Never test a cylinder for leaks with an open flame; use a solution of soapy water. Always protect the hose from hot slag and cuttings and from being tramped on or from being run over by vehicles. Never force hose connections that do not fit. Do not use white lead, oil, grease, or other pipe-fitting compounds for connections on hoses, torch, or other fittings. Never crimp a hose to shut off the gas flow. Do not tape hoses together. Periodically, examine all hoses for leaks by immersing them in water while under pressure.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The process of severing ferrous metal by means of the chemical action of oxygen on the elements in the base metal is called

a. carbon-arc cutting.
b. flame treating and cutting.
c. metal-arc cutting.
d. oxyacetylene cutting.

2. The jet coming from the center orifice of a cutting torch tip is

a. acetylene.
b. oxygen.
c. hydrogen.
d. carbon dioxide.

3. The streams coming from the smaller orifices surrounding the center tip orifice are for

a. preheating.
b. post heating.
c. cutting.
d. oxidizing.

4. For torch-cutting a plate 7/8 inches thick, the recommended tip size number would be

a. 0.
c. 1.
c. 2.
d. 3.

5. For cutting metals using the oxyacetylene process, the amount of acetylene pressure used in relation to the oxygen pressure is

a. much lower.
b. much higher.
c. the same.
d. alternately higher, than lower.

6. The preheating flames of a cutting torch are adjusted to obtain a (an) __________ flame.

a. reducing
b. oxidizing
c. normalizing
d. neutral

7. In starting a straight cut in the center of a metal sheet, you would tilt the torch at a 45° angle from the perpendicular in line with the cut in order to

a. provide proper starting bevel.
b. eliminate slag blow back.
c. preheat properly.
d. eliminate spark shower.

8. A suitable torch guide for cutting beveled edges is a

a. 1-inch angle iron with the angle up.
b. protractor bevel with extension.
c. chalk line.
d. special tip with steel guides.

9. The best way to cut a bevel in a piece of heavy pipe is to

a. make a continuous cut around the pipe.
b. hold the tip at a 45° angle to the center of the pipe.
c. oscillate the cutting tip.
d. cut the tip off square, then bevel it.

10. The purpose of rotating the torch when piercing a hole is to

a. blow molten slag out of the hole.
b. ensure a round hole.
c. distribute the cutting heat evenly.
d. ensure proper preheating.

11. An expedient tool for removing rivets is

a. a cold chisel.
b. a cutting torch.
c. a file.
d. a grinder.

12. To avoid forming a hard layer along the edges when torch-cutting high-carbon and alloy steels, you should

a. preheat the edges ahead of the cut.
b. postheat the edges after the cut.
c. use a oil bath for quenching.
d. machine the edges with a grinder.

13. Cast iron is more difficult to cut than steel because

a. steel must be preheated to a higher temperature than cast iron.
b. it requires a much smaller oxygen pressure than steel.
c. it melts at a lower temperature than does its oxides.
d. it is more brittle than steel.

14. A good cutting speed with the cutting torch will produce

a. irregular drag lines.
b. very little spark shower.
c. uniform drag lines forming sweeping curves.
d. drag lines that are straight up and down.

15. Acetylene working pressure in excess of __________ psi must be avoided.

a. 15
b. 20
c. 25
d. 30

16. The best way to check for cylinder leaks in oxacetylene welding equipment is by using

a. a match.
b. soapy water.
c. test paste.
d. compressed air.

Work Unit 3-5. WELDING EQUIPMENT TROUBLESHOOTING

IDENTIFY TWO MAJOR MALFUNCTIONS IN OXYACETYLENE EQUIPMENT AND HOW TO TROUBLESHOOT THE MALFUNCTIONS

IDENTIFY THE TROUBLESHOOTING PROCEDURES FOR THE LM-62 METALLIC-ARC WELDER.

IDENTIFY THE TROUBLESHOOTING PROCEDURES FOR THE DYNAMOTOR WELDER.

Oxyacetylene equipment troubleshooting.

a. Regulator malfunctions and corrections. Leakage of gas between the regulator seat and the nozzle is the principal trouble encountered with regulators. It is indicated by a gradual increase in pressure on the working pressure gage when the adjusting screw is fully released or is in position after adjustment. This defect, called "creeping regulator" in the welding trade, is caused by cracked or worn valve seats or by foreign matter lodged between the seat and the nozzle. Regulators with such leaks should be repaired immediately to avoid damage to other parts of the regulator or injury to personnel. This leakage is particularly dangerous in acetylene regulators because acetylene at high pressure in the hose is a definite explosive hazard. To correct this malfunction, remove and replace the seat if it is worn, cracked, or otherwise damaged. If the malfunction is due to fouling by dirt or other foreign material, clean the seat and nozzle thoroughly and blow out any dust or dirt in the valve chamber. Broken or buckled gage tubes and distorted or buckled diaphragms are usually caused by backfire at the torch, by leaks across the regulator seats, by failure to release the regulator adjusting screw fully before opening the regulator seats, or by failure to release the regulator adjusting screw fully before opening the cylinder valves. Defective Bourdon tubes (flattened, semicircular tube, connected to the dial indicator) in the gages are indicated by improper action of the gages or by escaping gases from the gage cages. Gages with defective Bourdon tubes should be removed and replaced since satisfactory repairs cannot be made without special equipment. Buckled or distorted diaphragms cannot be adjusted properly and should be replaced with new ones. Rubber diaphragms can be easily replaced by removing the spring case with a vise or wrench. Metal diaphragms are sometimes soldered to the valve case and their replacement is a special repair shop job. It should not be attempted by anyone not familiar with the work.

b. Torch malfunctions and corrections. Improper functioning of the welding torches is usually due to one or more of the following causes: Leaking valves, leaks in the mixing head seat, scored or out of round welding-tip orifices, clogged tubes or tips, or damaged inlet connection threads. These defects are the cause of gas leaks and, unless corrected immediately, may cause flashbacks or backfires with resultant injury to the operator, and damage to the welding equipment. Valve leakage is usually due to bent or worn stems, damaged seats, or a combination of both. Loose packing will also cause leaks around the valve handle. Such leaks are indicated when the gases continue to flow after the valves are closed. Bent or worn valve stems should be replaced and damaged seats should be refaced. Loose packing may be corrected by tightening the packing nut or replacing the packing, making certain that the packing nut is tight. Leaks in the mixing head are indicated by the popping out of the flame and by the emission of sparks from the tip, accompanied by a squealing noise. Leaks in the mixing head will cause improper mixing of the oxygen and acetylene which, in turn, will cause flashbacks (ignition of the gases back of the mixing head in the tubes). A flashback causes the torch handle to suddenly become very hot. This defect can be corrected by reaming out and turning the mixing head. Special reamers are needed for this operation, and it should not be attempted by anyone not having the proper equipment to do the job.

Scored or out-of-round tips will cause the flame to be irregular even after the tip has been cleaned. They cannot be repaired and must be replaced. Clogged tubes and tips are usually due to carbon deposits caused by flashbacks or backfire or to the presence of foreign matter that has entered through the hoses. Great working pressures will be required to produce the flame required for some tips, and the flame will be distorted. To correct this condition, the torch should be dismantled and each component (tip, mixing head, and hose) should be cleaned out and blown out with oxygen at pressures of 20 to 30 psi. The tip and mixing head should be cleaned, first with soft copper or brass wire or with cleaning drills of the proper size, and then blown out with oxygen. The cleaning drills should be approximately one drill size smaller than the tip orifice to avoid enlarging the holes. Leaks due to damaged inlet connection threads can be detected by closing the needle valves and the cylinder valves. Such leaks will cause the regulator pressure to drop. Also, if the threads are damaged, the hose connections at the torch inlet will be difficult or impossible to tighten. Unless corrected, this condition may cause fires by ignition of the leaking gases which could result in serious injury to the operator or damage to the equipment. To correct this, the threads should be recut with a thread chaser and the connections thoroughly cleaned.

Troubleshooting the Model LM-62 Metallic-Arc Welder

Table 3-1 below provides information that is useful in diagnosing and correcting the failures of the welder.

Table 3-1. Troubleshooting Procedures for the LM-62 Metallic-Arc Welder.

Symptom	Probable cause	Possible remedy
a. Welding generator fails to generate sufficient voltage	Generator speed too low.	Increase speed.
	Brushes scored or worn.	Replace brushes.
	Commutator scored.	Repair commutator.
	Armature circuits open.	Check, repair, or replace armature.
	Wiring short-circuited.	Check, repair, or replace.
	Commutator dirty.	Clean commutator.
	Brushes sticking in holders.	Adjust spring pressure.
	Panel cable connections defective.	Inspect and repair.
	Load excessive.	Reduce load.
	High mica on commutator.	Undercut mica.
	Rheostat defective.	Replace rheostat.
b. Current fails or becomes low	Welding cable defective.	Replace cable.
	Electrode holder defective.	Replace holder or repair.
	Panel wiring defective.	Inspect and repair
	Ground connections poor.	Tighten ground connections.
	Cable connections loose.	Tighten cable connections.
c. Welding generator voltage too high	Speed too fast.	Reduce speed.
	Rheostat defective.	Replace rheostat.
d. Voltage becomes erratic	Generator speed erratic.	Inspect and adjust engine for steady speed.
	Commutator dirty.	Clean commutator.
	Brushes scored or worn.	Replace brushes.
	Commutator scored.	Repair commutator.
	Insufficient brush spring pressure.	Adjusting spring pressure.
	Brushes sticking in holders.	Inspect and repair.
	High mica on commutator.	Undercut mica.
	Rheostat defective.	Replace rheostat.
e. Welding arc becomes noisy and spatters	Current setting too high.	Reduce current setting.
	Polarity wrong.	Check polarity, try the reverse polarity, or try an electrode of an opposite polarity.

Table 3-1. Troubleshooting Procedures for the LM-62 Metallic-Arc Welder (continued).

Symptom	Probable cause	Possible remedy
f. Welding arc becomes sluggish	Current too low.	Adjust current.
	Connections poor.	Check and tighten all loose connections; check for corroded or split connections.
	Cables too long.	Check cable drop. Use shorter cables.
g. Touching welder gives shock	Welder not properly grounded.	Ground welder properly.
	Welder covered with water or moisture.	Wipe off and dry thoroughly.
h. Electrode holder becomes hot	Electrode holder spring weak or soft.	Replace spring.
	Electrode grooves dirty.	Clean and file grooves.
	Cable connections corroded.	Clean and make new, tight connections.

Troubleshooting the Dynamotor-Welder (Also a Metallic-Arc Welder)

Table 3-2 provides information that is useful in diagnosing and correcting the failures of the welder.

Table 3-2. Troubleshooting Procedures for the Dynamotor-Welder.

Symptom	Probable cause	Possible remedy
a. Welder noisy	Mounting hardware loose.	Tighten or replace hardware.
	Shock absorber loose or defective.	Tighten or replace shock absorber.
b. Welder overheats	Ventilator air filters clogged or dirty.	Clean ventilating filters.
c. Welder will not start when shop set engine is used	Clutch not engaging.	Adjust clutch.
	Drive belts defective or worn out.	Adjust or replace drive belts.
d. Welder will not start when external power is used	Dynamotor switch not properly actuated.	Properly actuate switch.
	Dynamotor switch defective.	Replace dynamotor switch.
	Power selector switch in wrong direction.	Set power switch to position marked CITY on panel.
	Power selector switch defective.	Replace power selector switch.
e. Welder starts but rotates in wrong direction	External power lines incorrectly connected.	Interchange any two incoming leads.
f. Welder will not deliver ac when shop set is used	Dynamotor switch defective.	Replace switch.
	Dc ammeter electrical leads open or shorted.	Repair or replace ammeter electrical leads.
	Dc ammeter defective.	Replace dc ammeter.
	Dc ammeter shunt defective	Replace dc ammeter shunt.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. To prevent buckling and distorting of the diaphrams in the regulator, you would

   a. release the adjusting screw fully before opening the cylinder valves.
   b. shut off the cylinders first.
   c. always blow out the gas hoses.
   d. stabilize the acetylene flame before opening the oxygen valve.

2. A gradual increase in pressure on the working pressure gauge after the adjusting screw is fully released is an indication of a

   a. broken gauge tube.
   b. leaking torch valve.
   c. worn valve seat.
   d. scored welding tip orifice.

3. You suspect a leakage of gas in your gas-welding regulator; specifically, between the regulator seat and the nozzle. This leakage is indicated by

   a. a total lack of pressure on the working pressure gauge.
   b. an increase in pressure on the working pressure gauge.
   c. a decrease in pressure on the working pressure gauge.
   d. the formation of bubbles around the nozzle.

4. A cutting torch tip should be cleaned with

   a. soap and water.
   b. a steel brush.
   c. a soft copper/brass wire or cleaning drills of the correct diameter.
   d. emery cloth or sand paper.

5. While using the LM-62 welder you receive a shock, the problem is

   a. the commutor is dirty.
   b. the polarity is wrong.
   c. the welder is not properly grounded.
   d. the electrode holder spring is weak or soft.

6. When the dynamotor-welder starts but rotates in the wrong direction, the problem is the

   a. external powerlines are incorrectly connected.
   b. drive belts are defective or worn out.
   c. dynamotor switch is defective.
   d. dc ammeter defective

Work Unit 3-6. INERT-GAS-ARC WELDING

IDENTIFY THE OPERATION, PROCEDURES AND TECHNIQUES OF INERT-GAS-ARC WELDING.

a. "Gas shielded welding" is a term used to designate the fusion (melting together) welding process that uses an inert gas (helium or argon) to shield a tungsten electrode and the molten pool of metal from the atmosphere. The shielding gas flows from orifices located in the torch head forming a protective blanket over the weld area. This blanket protects the arc and the molten pool of metal from the harmful effects of the atmosphere. Because of this complete protection from the atmosphere, gas-shielded welds are stronger, more ductile, and more corrosion-resistant than welds made by the ordinary metallic-arc process. Gas-shielded welding is ideal for welding metals such as aluminum, magnesium, stainless steel, monel, brass, and copper. This is virtually the only process with which you can successfully weld magnesium. With the Marine Corps emphasis on equipment that can be helilifted, it is necessary that equipment be light in weight. Consequently the new breed of equipment being acquired by the Corps has increased the use of lightweight materials such as aluminum, magnesium, and aluminum alloys. Consequently, the use of inert-gas-arc welding is becoming more prevalent throughout the Corps.

(1) Shielding gases used. Helium and argon are inert gases that are used in gas-shielded welding. The term "inert gas" indicates a chemically inactive gas; unlike oxygen, it will not mix with any other element. Whether the welder uses helium or argon depends on what results he wants. In some cases, helium is preferable to argon because it produces more heat per ampere of welding current, if other factors are equal. This characteristic becomes a disadvantage when welding very light gages of metal (1/32 inch or less). Here arc stability becomes a very important factor. With higher current settings, it is better to use argon with its lower arc voltage. Both gases are plentiful and helium is much cheaper than argon, but you will use three times more of it to do the same job. This is because of the different weights of the gases. As helium is several times lighter than argon, it will not settle down around the work as effectively as argon. Argon is a colorless, odorless, inert gas somewhat heavier than air. The normal atmosphere contains 0.93% by volume or 1.29% by weight of this element. It is also a nontoxic nonflammable gas. Argon comes in cylinders similar in size and shape to oxygen cylinders, from 200 to 250 cu. ft. under pressure at 1800 to 2280 psi. You can identify the cylinders by the distinctive color markings of gray with a white band. When the cylinder drops to 25 psi, you can consider the cylinder to be empty. Use the same care when handling or storing argon gas as you would when handling any other gas.

(2) Cleaning welding surfaces. Cleaning the surface to be welded is of major importance regardless of the welding process. This cleaning should be done just prior to welding. Oxides, grease, and oil film remaining on the edges to be joined cause unsound welds. Unsoundness reduces the mechanical and electrical efficiency of the weld. Mildly alkaline solutions and commercial degreasers that do not emit toxic fumes during welding are used successfully to remove surface contaminants before welding. One common method is for the welder to wipe the edges to be joined with a cloth dipped in solvent, such as alcohol or acetone. All welding surfaces should be dried after cleaning to prevent porosity in the weld metal. Use the method that will produce the degree of cleanliness you require. The method will, of course, depend on the type of contamination to be removed, the composition and design of the part you wish to clean, and the quality of the surface finish to be retained. Things to remember when you are trying to do a better job of cleaning are as follows:

Use mechanical cleaning where excessive amounts of easy-to-remove dirt are present in any form, provided you do not lessen the usefulness of the part.

Never use solvents or chemical baths unless you observe the required safety and fire regulations.

Use solvent cleaning to remove grease and oil contamination that you cannot eliminate by mechanical cleaning alone. This implies that you can use a combination of mechanical and solvent cleaning.

When using oil-base solvents such as kerosene, naphtha, and distillate alkaline, cleaning is usually necessary to remove the oily film left by the solvent cleaning agent.

You can use the wire brush method of cleaning to remove light coats of paints and primers, natural oxide films, and light coats of corrosion.

b. Inert-gas-welding equipment. The Linde Welding Set, Model SWM-9, used by the Marine Corps, is designed for continuous duty, semiautomatic welding of aluminum, using a consumable aluminum electrode shielded by inert argon gas. The welding set can be used for either short arc welding, with a constant potential power supply, or conventional welding, with a constant-current power supply. The welding set consists of a control assembly, welding torch, argon gas regulator, and the necessary hoses and cables.

(1) Torch (fig 3-17). The torch is an air-cooled hand welding torch rated for a maximum current capacity of 200 amperes dc continuous duty. The torch will provide the full range of wire feed speeds required to handle all welding applications using 3/64"-diameter aluminum wire. The same torch will weld metal from 0.093 in. to 0.125 in. thick using 0.030 in. aluminum wire at current levels up to approximately 125 amperes. The torch is well balanced and weighs approximately 3 lb, less cables. It is of rugged all-metal construction and is adequately insulated to afford the operator complete protection from the wire and from other parts that are electrically hot. Simple in design and operation, the torch is used with a direct current conventional constant-current type of welding power supply.

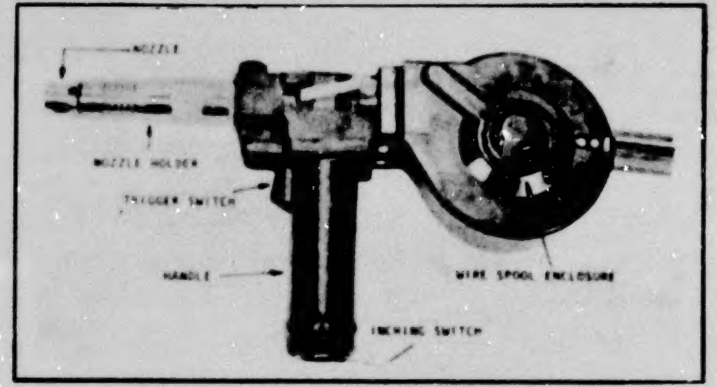

NOZZLE
NOZZLE HOLDER
TRIGGER SWITCH
HANDLE
WIRE SPOOL ENCLOSURE
INCHING SWITCH

Fig 3-17. Inert-gas-shielded model SWM-9 torch.
(Currently in use in the Marine Corps)

(2) Voltage control (fig 3-18). The arc voltage is controlled by a series-type voltage control operated from a 115-volt ac or dc power source. It actuates the welding current and flow of argon by turning these services on or off in proper sequence for maximum utility and safety, and at minimum operating cost. The control also allows the operator to inch the wire along without the welding power supply being energized.

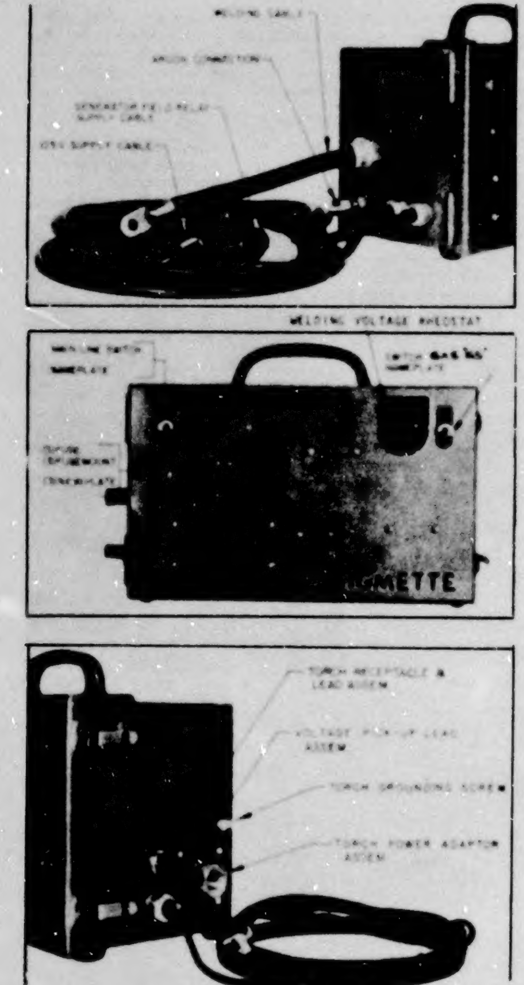

WELDING CABLE
ARGON CONNECTION
GENERATOR FIELD RELAY SUPPLY CABLE
115V SUPPLY CABLE
WELDING VOLTAGE RHEOSTAT
MAIN LINE SWITCH NAMEPLATE
SWITCH "ON & OFF" NAMEPLATE
METTE
TORCH RECEPTACLE & LEAD ASSEM
VOLTAGE PICK-UP LEAD ASSEM
TORCH GROUNDING SCREW
TORCH POWER ADAPTOR ASSEM

Fig 3-18. Voltage control assembly.

(3) Argon gas regulator and flowmeter (fig 3-19). This is a 2-stage, constant-flow regulator equipped with an adjusting valve, a pressure regulator (indicates the pressure of the argon gas flowing into the regulator), and a flowmeter (measures the amount of argon flowing from the regulator through the hose to the torch). The gas coming into the regulator is measured by the gage in pounds per square inch (psi). The gas going to the hose is measured by the flowmeter in cubic feet per hour (cfh). The flow of argon is regulated by an adjusting valve located on the regulator.

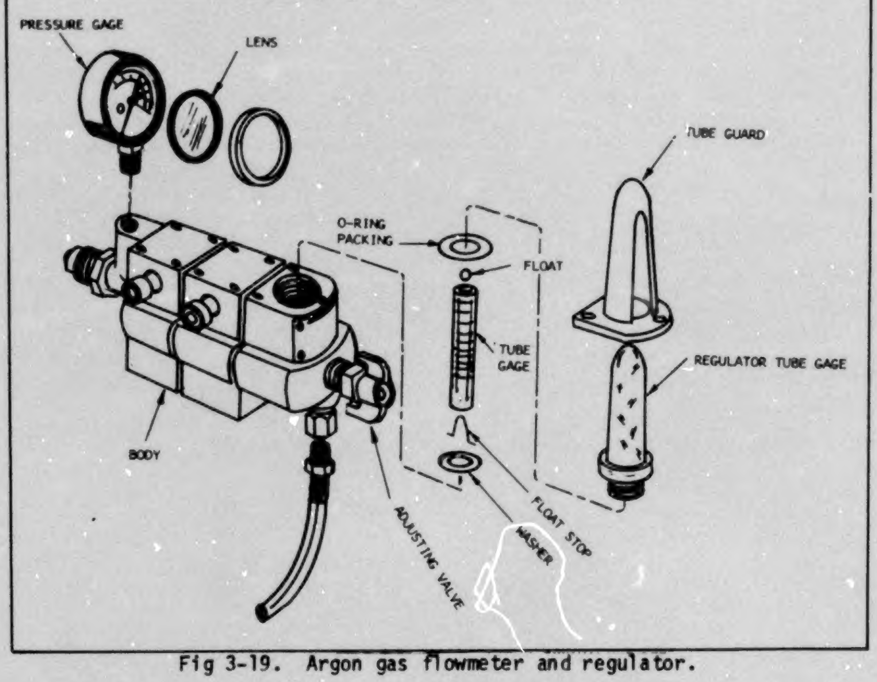


Fig 3-19. Argon gas flowmeter and regulator.

(4) Adjustment and operation of SWM-9. The sigmette outlets are located at the bottom left of the LM-62 generator control panel. The welding selector switch, located in the center of the generator control panel, should be in the MIG position. The welding polarity switch should be in the "reverse polarity" position. The argon gas switch (GS) on the control box controls the gas solenoid valve. When the mainline switch (MLS) is turned on, the GS is placed in the "auto" position. The gas solenoid valve will be energized when the field interrupter relay is energized. To check the gas flow without energizing the contractor, place the GS in the manual position. Adjust the flowmeter on the shielding gas regulator to obtain the desired rate of gas flow. After making necessary adjustments, return the GS to the "auto" position. Power for the wire feed switch is provided by the permanent magnet type shunt motor in the torch. During the welding cycle, the welding wire feed rate is controlled by the welding voltage rheostat (WVR) on the voltage control assembly. Turning the WVR clockwise increases the arc voltage; turning it counterclockwise decreases the arc voltage. If the proper setting is not known, use a lower setting at the start to prevent a burnback. With the MLS in the "on" position and the argon and power supplies adjusted, the operator may start to weld by pressing the torch trigger switch. This closes the field interrupter relay which energizes the welding generator and also starts the flow of argon. Make sure that the end of the electrode wire extends approximately 1/2 in. beyond the end of the nozzle before starting to weld. The inching button can be used to inch the wire into this position. Touch the end of the wire to the workpiece. This establishes an arc and starts the wire feed at the rate indicated on the WVR. Welding will continue as long as the trigger switch remains depressed. Welding action will stop and all services will be discontinued if the trigger switch is released. The control is equipped with a protective circuit which will prevent the application of excessive voltage to the wire feed motor if the torch is withdrawn from the work to stop the welding action. However, the torch is not the proper method of breaking the arc and should be avoided.

c. Tungstern-inert-gas (TIG) welding process. The TIG process is widely used for welding relatively thin aluminum sections. In this process, under normal conditions, an arc is established between a nonconsumable tungsten electrode and the aluminum parts to be welded, with a shield of inert gas enveloping the arc and the weld pool. The arc melts the aluminum base metal and bare filler rod of suitable alloy is manually added to the molten pool. Welding can be done rapidly from all positions. No flux is required in TIG welding because the action of the arc breaks up the oxide film and allows good metal flow. Since the heat of the tungsten arc is concentrated in a small area, it is much faster than gas welding. Also, distortion of the base metals is less than with gas welding.

(1) Power source. Both ac and dc are used in inert-gas welding. However, ac is used in welding aluminum and magnesium, since the cleaning action of the arc is more pronounced. Straight polarity has poor characteristics and the arc is difficult to handle. Welds made with dc are generally smoother in appearance than those made with ac. Welding transformers with built-in high-frequency current stabilizers to control the arc are available, but special attention should be given to their installation as a high-frequency circuit will cause radio and TV interference.

(2) Welding equipment and supplies. In addition to the power source, the following equipment is needed:

TIG welding torch

Inert-gas supply, regulator-flowmeter, hose, and fittings

Filler metal

Water supply and fittings

Helmet or eyeshields and protective clothing

For currents above 100 amperes, cooling the torch and power cable is necessary because of heat generated by the arc and the current passing through the cable. For welding currents below 100 amperes, air-cooled torches are satisfactory. A sectional view of a water-cooled torch is shown in figure 3-20. Water used to cool the welding gun should be clean to prevent clogging or flow restriction. Overheating can melt the silver-brazed metal joints in gun and the plastic water tube which shields the electric cable. A control mechanism is available which does not allow the welding current to start unless the water is flowing. Some TIG welding equipment is provided with a solenoid valve which automatically shuts off the water supply when the welding stops. This prevents excessive cooling and moisture condensation inside the torch. The TIG welding torch carries the welding current and directs the inert gas to the weld area. The torch must be properly insulated for maximum current ranges to insure operational safety. Current is transmitted from transformer through the power cable to the collet (metal ring) holding the tungsten electrode. Gas ports surrounding the electrode permit the inert gas to enter the nozzle. The electrode should extend beyond the end of the gas cup a distance equal to its diameter for butt welding and slightly further for fillet welding. The gas cup or nozzle of the torch can be either ceramic or metal.

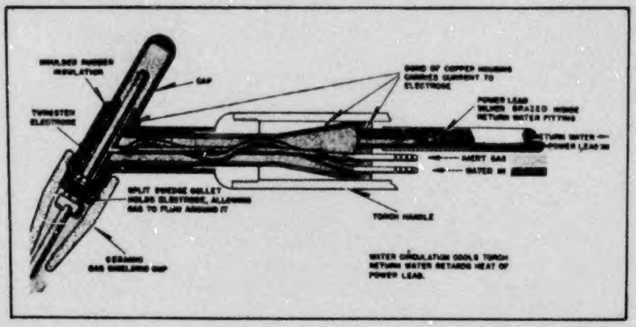

MOLDED RUBBER INSULATION
CAP
TUNGSTEN ELECTRODE
BODY OF COPPER HOUSING CARRIES CURRENT TO ELECTRODE
POWER LEAD SILVER BRAZED INSIDE RETURN WATER FITTING
RETURN WATER
POWER LEAD IN
INERT GAS
WATER IN
SPLIT WEDGE COLLET HOLDS ELECTRODE, ALLOWING GAS TO FLOW AROUND IT
TORCH HANDLE
CERAMIC GAS SHIELDING CUP
WATER CIRCULATION COOLS TORCH RETURN WATER RETARDS HEAT OF POWER LEAD.

Fig 3-20. Water-cooled inert-arc-gas welding torch.

(3) Welding technique. The operator controls the operation of the torch through a trigger or button mounted on the handle. Depressing the button or trigger actuates solenoids, which in turn start the flow of shielding gases and cooling water, and energizes the welding circuit. Control circuits are so arranged that the gas and water flow for a short period before and after the welding circuit is energized or shut off. This is a advantage, since it insures that shielding gas is available to protect the weld zone when welding begins and for a short period after welding stops. The arc is struck by bringing the tungsten electrode close to the work surface. The electrode does not have to touch the work surface as in metal-arc welding, because the high frequency establishes the arc. The arc is held at the starting point until the metal liquifies and a weld pool is established. Filler rod is then added manually (fig 3-21) from the front as needed to form a weld bead. The torch is usually pointed in the direction of travel with a 10° to 20° angle from the vertical position. The finished weld beads do not require cleaning since no flux was used in the process. The completed welds should have a smooth appearance. To avoid wasting the shielding gas and to obtain a good weld, you should proceed as follows:

Use a short arc. Reduce the amount of draft in the welding area. Use the minimum gas flow necessary to obtain consistently clean, sound welds.

Weld in the downhand position. Any change in work positioning to make this possible is advisable since it will greatly reduce welder fatigue, increase efficiency, and give faster welding.

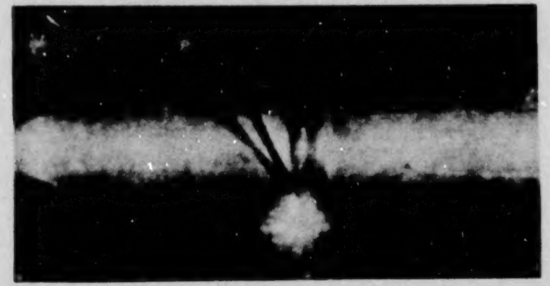


Fig 3-21. Applying filler rod.

d. Metal-inert-gas (MIG) welding process. MIG welding is another form of the inert shielded-gas method of welding in which a consumable electrode is used. The electrode is an integral part of the welding apparatus. MIG welding uses direct current and a shield of argon or helium gas. A small-diameter wire (electrode) serves as the filler metal and is automatically fed into the gun at high speed. The weld pool and the electrode are protected from oxidation by the shield of inert gas. No flux is required.

(1) Power source. Either a direct-current welding generator or rectifier can be used for MIG welding aluminum. Constant power source compensates for changes in arc length, thus providing more uniform welding. Reverse polarity (electrode positive) is used when aluminum is welded by this process. The MIG process deposits filler metal at high rates (compared with TIG welding), making faster, more economical welds with less heat effects on the workpiece.

(2) Welding equipment and supplies. In addition to the dc power source, the following equipment is needed:

Inert-gas supply, regulator flowmeter valve, hose, and fittings.

Filler wire, wire spool, and drive.

MIG welding unit.

Helmet or eyeshield and protective clothing.

There are several different designs of MIG welding units on the market, the major difference being the location of the filler wire drive mechanism. Of the two major designs of welding gun, one (model SWM-9) pulls the wire by means of drive rolls from within the gun itself. The other pushes the wire from the drive rolls through a long guide liner to the welding gun and the workpiece. The gun currently used in the Marine Corps is of the first type (fig 3-17). Both types have a control box unit which actuates the power, feed, shielding gas, and cooling water when the trigger on the gun is squeezed.

(3) Filler wire. Filler wire of types EC, 100, 4043, 5154, 4183, 5356, and others are available in 0.030-, 0.064-, 1/32-, 1/16- and 1/8-in. diameters. Special attention must be given to see that the wire is clean. Unsound welds result from using wire that has been contaminated with oils, grease, dirt, etc. Best welding results from using wire which has just been removed from its carbon. Wire should be stored in a warm, dry area and kept covered. If welding is stopped for any length of time, remove the wire roll and place it in the original carton to prevent contamination.

(4) Welding technique. Filler wire alloy, current setting, and gas coverage can be chosen to suit the alloy and thickness of the material being welded. MIG welding equipment is designed to feed the wire and automatically start the gas flow as soon as the arc is struck. Welding progresses by moving the gun along the line of weld joint at such a rate as to build up a bead of the desired dimensions. Because of the shielding action of gas, no flux is needed. In flat-position welding, the gun is held pointed in the direction of travel at a 5° to 20° angle from the vertical position. When more than one pass is needed to complete the weld, it should be cleaned by brushing with a stainless wire brush. Postweld cleaning other than wire brushing is not usually necessary in MIG welding. Figure 3-22 shows welding currents used with different-size wires.

Filler wire diameter (inches)	Welding current (amperes)
0.040	120-210
1/16	165-300
3/32	240-450
1/8 a/	400 and up b/

a/ Normally used for automatic welding.
b/ Maximum welding current dependent on the power source.

Fig 3-22. Recommended current welding for various diameters of MIG filler wire.

EXERCISE: Answer the following questions and check your responses against those listed at the end to this study unit.

1. The material that was largely responsible for the development of the inert-gas-shielded welding method is

   a. aluminum.
   b. magnesium.
   c. stainless steel.
   d. monel.

2. All the gases listed below are inert EXCEPT

   a. argon.
   b. oxygen.
   c. helium.
   d. xenon.

3. A gray cylinder with a white band is identified to be

   a. argon.
   b. acetylene.
   c. oxygen.
   d. nitrogen.

4. The advantage of inert-gas-arc welding is

   a. no flux is required.
   b. more heat is produced by the arc.
   c. welds are stronger and more corrosion resistant.
   d. less spark shower.

5. The liquid recommended for cleaning surfaces to be welded by the TIG or MIG process is

   a. gasoline.
   b. carbon tetrachloride.
   c. trichorethylene.
   d. acetone.

6. In an inert-gas-arc welding setup, the special device that regulates the amount of argon gas going from the gas cylinder to the torch is

   a. oxygen regulator valve.
   b. argon valve.
   c. regulator-flow meter valve.
   d. torch regulator valve.

7. When you weld with the SWM-9 torch, the electrode should extend _________ beyond the end of the nozzle.

   a. 1/8 inch
   b. 1/4 inch
   c. 1/2 inch
   d. twice the diameter of the wire

8. When welding with the SWM-9 torch, and after all adjustments have been made, you start the flow of argon by

   a. turning on the GS.
   b. turning on the MLS.
   c. depressing the inching button.
   d. pressing the torch trigger switch.

9. The life expectancy of a tungsten electrode under normal operating conditions is

   a. 8 hours.
   b. 16 hours.
   c. 32 hours.
   d. indefinite.

10. On some TIG welding equipment, the device that automatically shuts off the water supply when the welding stops is the

    a. solenoid valve.
    b. voltage control.
    c. inching switch.
    d. flow meter adjusting valve.

11. In TIG welding, ______________ is used to cool the torch.

    a. helium
    b. water
    c. argon
    d. carbon dioxide

12. A tungsten electrode 1/8 inch in diameter should extend _________ inch beyond the gas cup of a TIG welder when welding a butt joint.

    a. 1/8
    b. 1/4
    c. 3/8
    d. 1/2

13. When welding with the MIG process, the welding current setting of 165-300 amperes requires a filler wire with a diameter of _________ inch.

    a. 1/32
    b. 1/16
    c. 3/32
    d. 1/8

14. MIG filler wire, normally used for automatic welding, requires a welding current range of

    a. 120 - 210 amperes
    b. 165 - 300.
    c. 240 - 450 amperes.
    d. 400 amperes and up.

SUMMARY REVIEW

In this study unit you learned to identify oxyacetylene welding equipment. You learned the procedures of oxyacetylene brazing, welding, and cutting of metals. Finally you learned Gas-Welding Safety Precautions, Welding Equipment Troubleshooting, and Inert-Gas-Arc Welding Procedures.

Answers to Study Unit #3 Exercises

Work Unit 3-1.

1. a.
2. b.
3. c.
4. c.
5. a.
6. a.
7. b.
8. c.
9. d.
10. a.
11. c.

Work Unit 3-2.

1. a.
2. a.
3. b.
4. d.
5. b.

Work Unit 3-3.

1. c.
2. d.
3. a.
4. The rod is kept ahead of the tip in the direction of welding.
5. The tip is kept ahead of the rod in the direction of welding.

Work Unit 3-4.

1. d.
2. b.
3. a.
4. c.
5. a.
6. d.
7. b.
8. a.
9. d.
10. a.
11. b.
12. a.
13. c.
14. c.
15. a.
16. b.

Work Unit 3-5.

1. a.
2. c.
3. b.
4. c.
5. c.
6. a.

Work Unit 3-6.

1. b.
2. b.
3. a.
4. c.
5. d.
6. c.
7. c.
8. d.
9. d.
10. a.
11. b.
12. a.
13. b.
14. d.

STUDY UNIT 4

METALWORKING MACHINES AND TOOLS

STUDY UNIT OBJECTIVE: UPON SUCCESSFUL COMPLETION OF THIS STUDY UNIT YOU WILL IDENTIFY THE USE OF METALWORKING MACHINES AND SPECIAL TOOLS UTILIZED WITHIN THE MARINE CORPS.

Work Unit 4-1. METAL CUTTING EQUIPMENT

IDENTIFY THE THREE TYPES OF SHEARS AND RELATED EQUIPMENT USED TO CUT METAL.

GENERAL

When you start any job in sheet-metal work there are several things that you always have to think about before you can actually do any work. Some of these are materials, layout precedures, forming processes, and tools needed. In other words, you have to know what materials you have to work with, how you are going to plan the job, how you are going to do it once it has been planned, and just what tools are going to be required to do the job. In many cases, the material you will be using will be determined for you, either by written or oral specifications. When you work from blueprints, the material is usually specified right on the print. When working from a sketch, you may have to find out from your supervisor just what kind of metal he wants and what gage or thickness is desired. Generally speaking, the shape of the object will determine the layout and the forming methods used. The use to which the object will be put will determine the kind of metal best suited for the job. You may work with sheets made of black iron, galvanized iron or steel, aluminum, copper-nickel, corrosion-resisting steel, copper, brass, or zinc. It is common practice when working with sheet metal to specify the thickness by gage number. Figure 4-1 gives the gage, thickness, and weight in pounds per square foot for galvanized (zinc-coated) and black iron (no protective covering) sheets--generally the two types that you will be working with. Some sheets have the gage stamped on them. If not, you will have to measure the thickness to determine the gage. Galvanized sheet usually measures 1 gage thicker than it actually is. This is due to the coat of zinc that is placed on the metal after it is rolled to a specified size. It is a good idea to check the sheet, whether it is marked or not. This will eliminate any errors or doubt. Sheet metal is tricky to work with. You will learn by experience how you can bend certain types. You will also learn, by experience, to be extremely careful when handling sheet metals by the edges, usually by cutting your fingers. Always file a fresh cut metal edge to remove burs and fishhooks.

Gage U.S.	Black Iron		Galvanized iron
	Thickness (inches)	Wt in lb per sq ft	Wt in lb per sq ft
32	0.0097	0.406	0.563
30	.0120	0.500	0.656
28	.0149	0.625	0.781
26	.0179	0.750	0.906
24	.0239	1.000	1.156
22	.0299	1.250	1.406
20	.0359	1.500	1.656
18	.0478	2.000	2.156
16	.0598	2.500	2.656
14	.0749	3.125	3.281
12	.1046	4.375	4.531
10	.1345	5.625	5.781

Fig 4-1. Gage, thickness, and weight of black and galvanized iron.

SHEARS

A metalworker must be familiar with the methods of cutting, bending, drilling, forming, and riveting metals. You should be familiar with the more common handtools and how to use them properly; for example, how to measure, drill, and use a file or hacksaw. Cutting sheet metal is a common occurrence; once a job is laid out, the next step is to cut it out.

The type of equipment used to do the cutting will depend, of course, on the thickness of the material to be cut. Thin pieces of comparatively soft metal may be cut more readily with hand snips. But for hard, thicker type metals, machines are used. These machines are divided into two groups; manually operated and power-operated. Each type of cutting machine has a definite cutting capacity which should never be exceeded. A few of the more common types available in maintenance battalions, depots, and base maintenance and repair facilities are described in this paragraph.

a. Squaring shears (fig 4-2). Squaring shears are used for cutting and squaring sheet metal. They may be foot-operated or power-operated. They consist of a stationary blade attached to a bed, and a movable blade attached to a crosshead. To make a cut, the work is placed in the desired position on the bed of the machine and the blade is moved through its downward stroke. The stroke of the cutter blade is always identical in its relation to the bed. A foot-powered squaring shear is equipped with a spring which raises the blade when pressure is taken off the foot treadle. A scale graduated into fractions of an inch is inscribed on the bed. Two side guides, consisting of thick steel bars, are fixed to the bed, one on the left and one on the right. Each is placed so that its inboard edge creates a right angle with the cutting edge of the bed. These bars are used to aline the metal when absolutely square corners are desired. When cuts other than right angles are to be made across the metal, the beginning and ending of the cut has to be marked in advance. Then the work is placed into position with the marks on the cutting edge of the bed, and the cut is made. A holddown mechanism consisting of holddown levers is incorporated in front of the movable cutting edge in the crosshead. Its purpose is to clamp the work firmly into place while the cut is being made. The clamp is quickly and easily operated by rotating the lever towards the operator's position. A firm downward pressure on the lever rotates the mechanism over center on its eccentric cam and locks the holddown in place. Reversing the action unlocks and releases the work. Three distinctly different operations, cutting to a line, squaring, and multiple cutting to a specific size, may be accomplished on the squaring shears. When cutting to a line, proceed as above. Place the beginning and ending marks on the cutting edge and make the cut. Squaring requires a series of steps. First, square one end of the sheet with one side. Then square the remaining edges, holding the one square end of the sheet against the side guard and making the cut. The remaining sides are squared one edge at a time in the same manner. When several pieces are to be cut to the same dimensions, make use of the adjustable gage stop with which most squaring shears are equipped. This stop is located behind the bed cutting edge and its purpose is to limit the amount of metal that can be slipped between the cutting edges of the blade and bed. The supporting rods for the stop gage are graduated in inches and fractions of an inch, and the gage bar is rigged so that it may be set and fixed at any point on the rods. With the gage set at the desired distance from the cutting blade, push each piece to be cut against the stop. You will be able to cut each piece to the same size without measuring each one. Not all squaring shears have a safety guard, but they should. No one sticks his fingers in the machine intentionally, but accidents do happen, and the safety guard is just one precaution well worth having on the machine. The shear should be operated by one man, but in case two are required for the job, extra care should be taken. If you are operating the treadle make sure your partner has his fingers clear before depressing it. The squaring shears were designed to cut flat sheet metal. NOT square, round, or bar stock. You will not only dull the blades, but serious damage to the machine will result. Other machines have been invented just for that purpose; use them.

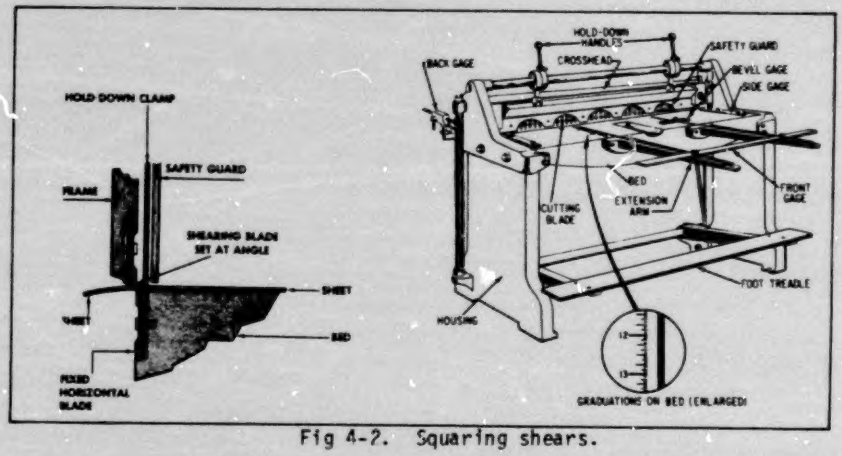


Fig 4-2. Squaring shears.

b. Throatless shears (fig 4-3). Throatless shears are constructed so that sheets of any length may be cut and the metal turned in any direction during the cutting operation. Thus, irregular lines can be followed, or notches made without distorting the metal. This type of shears is essentially an adaptation of heavy hand shears, in which the handles are removed, one blade secured to a base, and long lever attached to the movable blade.

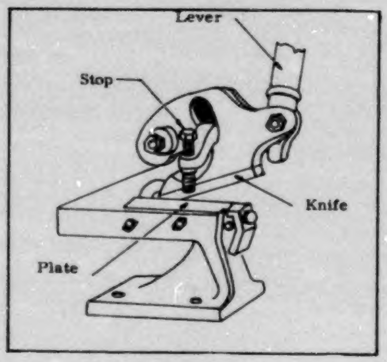


Fig 4-3. Throatless shears.

c. Hand bench shears. This type of shears is similar in operation to a papercutter. That is, it has a fixed blade, and a movable blade hinged at the rear. Since the blades are straight, they can be used only for cutting straight edges. For cutting metal that is narrower in width than the length of the blades, the cutting-edge lever can be pulled all the way down; however, for cutting larger pieces, a continuous series of short bites should be made, since complete closing of the blades tends to tear the sheet at the end of each cut. Some bench shears have a punching attachment on the end of the frame opposite the shearing blades, which can be used to punch holes in metal sheets.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The layout and the method used to form a sheet-metal object is determined by the

   a. weight of the metal.
   b. type of metal.
   c. size of the object.
   d. shape of the object.

2. The weight, in pounds per square foot, of a piece of 22-gage galvanized iron is

   a. 0.0290.
   b. 1.1250.
   c. 1.406.
   d. 3.2.

3. The squaring shears are designed to cut _________ stock.

   a. square
   b. sheet
   c. bar
   d. round

4. Devices for clamping sheet metal in place on a squaring shear are known as

   a. clamps.
   b. guides.
   c. holddowns.
   d. squares.

5. Shears which are used for notches, curves, and straight-line cuts on light sheet metal are known as

   a. throatless.
   b. hand bench.
   c. power shearing.

6. The type of shears used only for cutting straight edges are _________ shears.

   a. squaring
   b. throatless
   c. hand bench

Work Unit 4-2. SPECIAL TOOLS

LIST THE FOUR CATAGORIES OF SPECIAL TOOLS USED IN METAL WORKING.

Before discussing the tools individually, a few comments on the care and handling of hand tools in general might be appropriate. The condition in which a mechanic, metalworker, or anyone for that matter, maintains his tools, reflects his efficiency as well as the opinions of his superiors who judge his day-to-day work. Each tool should have its place and, when it is not used, it should be kept in its place. Each tool should be cleaned after each use before it is returned to its proper place, whether that place is in a toolbox or in a centrally located toolroom. If the tools are not going to be used again the same day, a light perservative coat of oil should be applied to prevent rust. Tools that are used on a workbench or at a machine should be kept within easy reach of the person using them, but in a place from which they will not be knocked off. Tools should not be placed on finished surfaces of any machine.

a. Snips (fig 4-4). Snips do just what their names imply; they snip or cut off pieces of metal. Unlike hacksaws, snips won't remove a wide area of metal when a cut is made. There is, however, more danger of causing minute metal fractures along the edges of the metal during the shearing process. For this reason, it is better not to cut exactly on the layout line in an attempt to avoid too much finish work. Cut as close to the line as is safe; there is no set rule for this distance. You can proceed safely, however, on the assumption that the thinner and softer the metal, the closer you can cut to the layout line. Some fractures are so severe that they cannot be removed when the metal is dressed. Leave about 1/32 in. for dressing. When cutting from the edge of a large sheet, you will have better luck if you cut from the left side. A small section of scrap material will curl upward (fig 4-4), while the larger piece of material will remain flat. When the left curls upwards, it provides clearance for the frame of the shears to advance along the cut. The cut should never be the full length of the blade. If the points of the snips are allowed to come together they will tear the metal as the cut is completed. Stop the cut before the end of the blades has been reached and take a new bite. When cutting heavy-gage metals, use only the rear portion of the snips. This not only reduces the possibility of springing the blades, but it gives greater leverage. Once a pair of snips are sprung, they are virtually useless. Hand snips will withstand a lot of hard use, but there is a limit to their endurance. Never use them to cut hardened steel wire or other similar objects. Such use only nicks, dents, or destroys the cutting edges of the blades. There are many types of snips used for special jobs. The ones described here are the more general types and ones that you will most likely handle. The straight hand snips (fig 4-5) have blades that are straight and cutting edges that are sharpened to the 85° angle. They can be obtained in sizes ranging from small 6-inch snips to the large 14-inch type. Designed to cut sheet metal up to 1/16 in., they are able to cut slightly heavier gages of aluminum alloy. It's a tough and crude job to try to cut circles and arcs with straight blade snips, so for this purpose specially designed snips are used. They are the circle, hawks-bill, trojan, and aviation snips (fig 4-5). Circle snips, with their curved blades, will handle any curve except the smaller ones. The hawks-bills are particularly useful in making curved cuts in large sheets. With their narrow curved blades, which are beveled enough to permit sharp turns without buckling the metal, the hawks-bill snips can cut either inside or outside circles of small radius. These as well as the circle snips must be used carefully, as their blades are easily sprung. The trojan snips are one of a group of snips known as "combination snips." The advantage of the trojan snips is that they can be used for several types of work; therefore, only one pair of snips is needed to handle the average sheet-metal job. They are rugged and should be used for heavier curved cuts, although their blades are small enough to permit sharp turns and they can be used to cut inside and outside curves. A special pair of snips resembling the trojans has been designed for cutting stainless steel. The cutting edges are inlaid alloy, and stamped on the handles are the words "For Stainless Steel Only." Do not use regular snips on stainless steel and do not use stainless steel snips on brass, copper, or galvanized or sheet iron. Another popular type is the aviation snips.

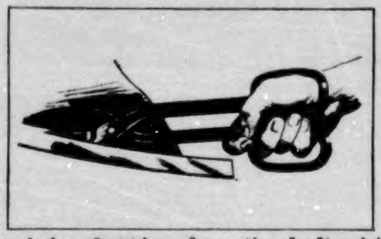


Fig 4-4. Cutting from the left side.

They have narrower cutting blades operated by a compound lever action which enables considerable pressure to be exerted on the blades with less effort being applied to the handles. These snips are used for cutting circles, squares, and irregular patterns. The hardened cutting blades make it easier to cut hardened materials. Many snips of this type have small serrations or notches on the cutting edges which prevent them from slipping backwards when a cut is made. Although this feature makes the cutting a little easier, it mars the edges of the metal slightly. You can remove cutting marks if you allow proper clearance for dressing the metal after cutting.

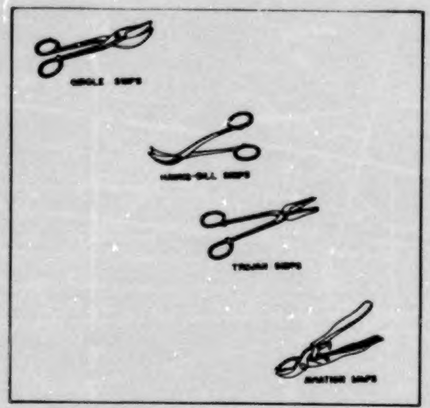


Fig 4-5. Types of hand snips.

b. Riveting tools.

(1) Rivet cutters (fig 4-6). In case you cannot obtain rivets of the required length, rotary rivet cutters are used to cut longer rivets to the required length. When using the cutter insert the rivet part way into the correct-diameter hole, place the required number of shims (shown as staggered, notched strips in the illustration) under the head, and squeeze the handles. The compounded action from the handles rotates the two disks in opposite directions. This shears the rivet smoothly to the correct length. When using the larger holes, place one of the handles in a vise, insert the rivet, and shear it by pulling on the free handle. If this tool is not available, diagonal cutting pliers can be used, although the sheared edges will not be as smooth and even as when cutting with the rivet cutter.

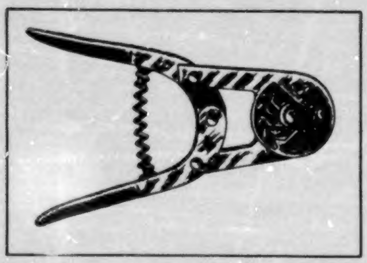


Fig 4-6. Rotary rivet cutter.

(2) Rivet set (fig 4-7). A rivet set is a tool equipped with a die for driving a particualr type of rivet. Rivet sets are used in both hand and pneumatic hammer riveting methods. They are available to fit any size and shape rivet. The ordinary hand set is made of 1/2"-diameter carbon steel, is about 6 inches long, and knurled to prevent slipping in the hand. Only the face of the set is hardened and polished. Sets for the universal, round, brazier, and oval-head rivets are recessed (or cupped) to fit the rivet head. In selecting the correct set, be sure that it will provide the proper clearance between the set and the sides of the rivet head and between the surfaces of the metal and the set. Flush or flat sets are used for countersunk and flathead rivets. In order to set flush rivets properly, the flush sets should be at least 1 in. in diameter. Special sets, called "draw" sets, are used to "draw up" the sheets being riveted in order to eliminate any openings between them before the rivet is bucked. Each draw set has a hole 1/32 in. larger than the diameter of the rivet shank for which it was made.

Sometimes, especially in handworking tools, the draw set and the rivet header are incorporated into one tool. The header part consists of a hole sufficiently shallow for the set to expand the driven rivet and form a head on it when the set is struck by a hammer. Figure 3-7 illustrates a rectangular-shaped handset which combines the draw and header sets, and a flush set used with a pneumatic hammer. Sets used with pneumatic hammers (rivet guns) are provided in many sizes and shapes to fit the type and location of the rivet. These sets are the same as the handsets except that the shank is shaped to fit the rivet gun. The sets are made of high-grade carbon tool steel and are heat-treated to provide the necessary strength and wear resistance. The tip or head of the rivet set should be kept smooth and highly polished at all times to prevent marring of the rivet head.

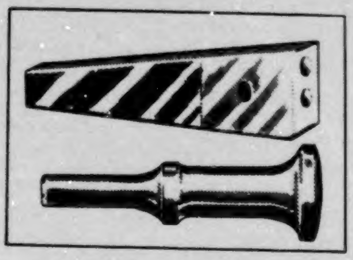


Fig 4-7. Rivet sets.

(3) Bucking bars (fig 4-8). To form rivets with the rivet set, a bucking bar is used to form "bucktails" (the heads formed during riveting operations) on rivets. Bucking bars are normally made of an alloy steel similar to tool steel. The particular shape to be used depends on the location and accessibility of the rivet to be driven. The size and weight of the bar depend on the size of the rivet being used. The portion of the bar designed to come in contact with the rivet has a polished surface to prevent marring of the formed bucktails. These bar faces must be kept smooth and perfectly flat and the edges and corners rounded at all times. A satisfactory rivet installation depends on the condition of the bucking bar and the ability of the metalworker using it. If possible, hold the bucking bar in such a manner as to allow the longest portion of the bar to be in line with the rivet. Hold the bar lightly but firmly against the end of the rivet shank so as not to unseat the rivet head. The inertia of this provides the force that bucks (upsets) the rivet, forming a flat, headlike bucktail.

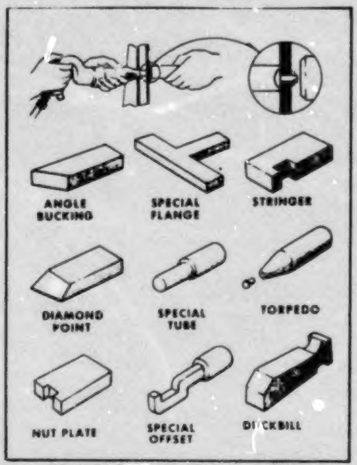


Fig 4-8. Bucking bars.

c. Striking tools. Generally speaking, this group of tools is composed of various types of hammers and mallets, all of which are used to apply a striking force where the force of the hand alone is sufficient. The metalworking hammers are divided into two classifications, hard face and soft face. The hard-face hammers are made of forged tool steel while the soft-face are made of wood, brass, lead, rawhide, hard rubber, or plastic. The metal-headed hammers are usually classified according to the weight of the head less the handle. The 4-oz and 6-oz sizes are used for light work, such as tapping a prick punch or a small drift punch. The 8- 10- and 12-oz sizes are best for general utility work; the 1-lb and heavier sizes are used for heavy-duty jobs.

(1) Hard face (figure 4-9). One of the best known general-purpose hammers is the ball peen, often called machinist's hammer. The ball end is known as the peening end and the flat end is the face. A couple of cousins to the ball peen are the straight peen and cross peen. Both have wedge-shaped peening ends. The face end is the same as the ball peen. A riveting hammer is used for forming metal as well as for driving rivets, and if you are forming sheet-metal seams, you will need a setting hammer, which is designed for getting into tight corners and for forming metal at right angles. The planishing hammer has two metal heads with slightly convex faces. The heads may be round, square, or a combination of both. Planishing hammers are lighter than most hammers and are primarily used to smooth out metal surfaces that have been bent out of shape. For planishing, the metal is laid on a smooth surface, such as forming blocks or a stake, and the irregularities are lightly struck with the hammer until smooth. Avoid glancing blows as these will cause the metal to stretch.

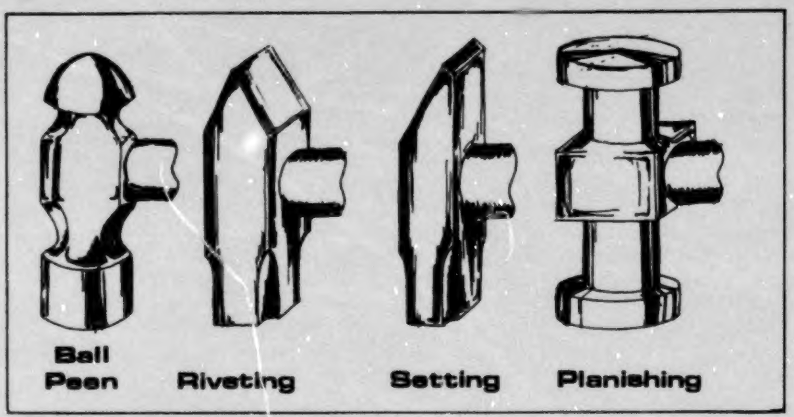


Fig 4-9. Hard-face hammers.

(2) Soft face (fig 4-10). These hammers have faces of rawhide, wood, plastic, copper, or pyralin. As a general rule, wood does not make a satisfactory soft-face hammer since it is likely to splinter. A closely wound rawhide mallet is very satisfactory and will stand a surprising amount of abuse. Do not use it on punches or objects having small diameter as they will destroy the surface of the face. A more elaborate soft-face hammer features the replacable tips which are clamped in the head of the hammer. Tips are made of rawhide, babbitt, or copper. The mallet is a hammerlike tool made of hickory, rawhide, or rubber, and is used for pounding down seams and forming metal sheets over stakes. A mallet will not dent or mar the metal as will a steel hammer.

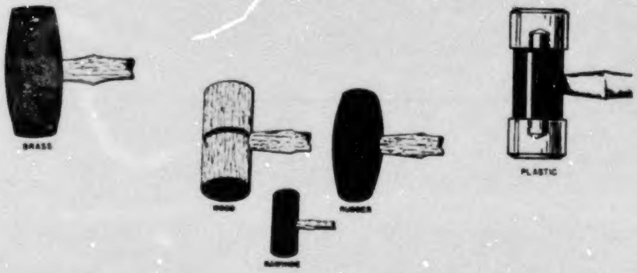


Fig 4-10. Soft-face hammers.

d. Layout tools. The tools you will most often use in laying out sheet-metal patterns will be the scriber, dividers, flat steel square, trammel points, circumference rule, prick punch, center punch, and combination square.

(1) Combination square (fig 4-11). The combination square may be equipped with any of the heads illustrated. Equipped with a square head, it can be used to lay off lines or to check work at either 90° or 45°. It can also be used to score a parallel line at a given distance from an edge, or to check a given thickness or depth by setting the end of the blade the given distance from the 90° face on the squarehead. Equipped with a protracter head, the square can be used to lay off lines or to check work at any angle. Equipped with the center head, it can be used to find the center of round stock.

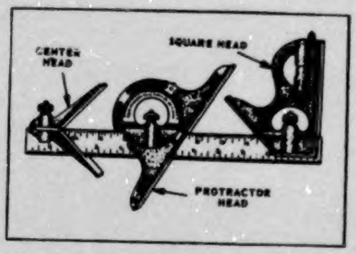


Fig 4-11. Combination Square.

(2) Dividers (fig 4-12) and trammel points (fig 4-13). Dividers have many uses, most of which are fairly obvious. Probably their principal use is transferring measurements from scale to work and vice versa. They are also used to divide a given length into equal segments and to scribe circles on stock. The trammel (fig 4-13) serves the same purpose as the dividers, but can be extended to cover measurements which are beyond the capability of the dividers.

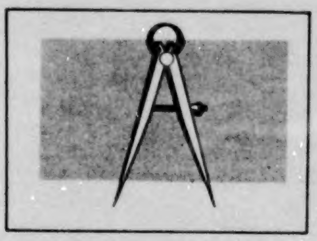


Fig 4-12. Dividers.

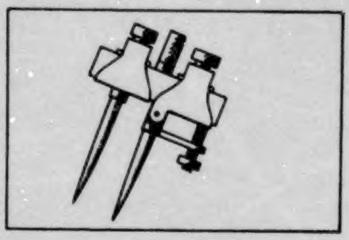


Fig 4-13. Trammel points.

(3) Punches (fig 4-14). Punches are used to locate centers for drawing circles, to start holes for drilling, or to punch holes in thin sheet metal. They are generally classified as to their design and intended use, for example, prick punch, center punch, pin punch, etc. Center punches are used to start the hole to be drilled with a twist drill. The point of the punch is ground to a 90° taper. The prick punch is used to locate points on sheet metal and to mark centers for circles. The shank of the punch is ground to a 30° taper. Its use is limited strictly to "pricking" the sheet-metal surface to mark a point and it should not be used in place of the center punch. The pin punch, with its long straight shank, is used for driving out straight and taper pins, rivets, etc.

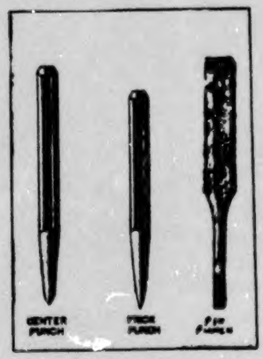


Fig 4-14. Types of punches.

(4) Measuring tools (fig 4-15). Rules are graduated measuring instruments made of wood or metal. The graduations are in inches and fractions of an inch or in centimeters and millimeters. The most common ones used by the metalworker are the flexible steel tape, the machinist's 6-inch steel rule, and the carpenter's steel square. The metalworker will find that the flexible steel tape is suitable for most purposes. The carpenter's square, although basically a carpenter's instrument used for laying out woodwork, is a very good instrument for laying out jobs on large sheet-metal surfaces.

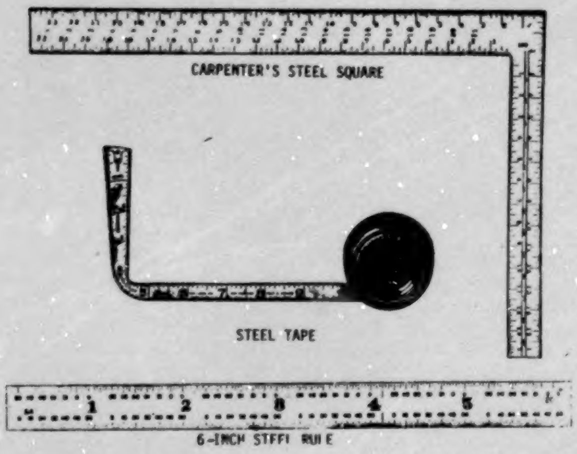


Fig 4-15. Tools used for measuring and layouts.

(5) Scriber (fig 4-16). The scriber is used for marking lines on metal, especially when measuring with a rule. The bent end is convenient for marking inside of cylindrical objects or partially closed recesses. Keep the scriber sharp and use it like a pencil with only enough pressure to make a clear mark.

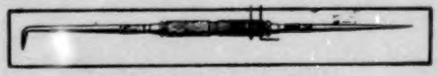


Fig 4-16. Scriber.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. An inside circle having a small radius should be cut with

a. bench shears.
b. combination shears.
c. squaring shears.
d. hawks-bill snips.

2. Snips designed for cutting sheet-metal up to 1/16-in thick and aluminum alloys of slightly heavier gage are known as

a. straight hand.
b. circle.
c. aviation.
d. trojan.

3. When you bring two pieces of metal together with a rivet set to eliminate any opening between them, your action is referred to as

a. backing.
b. drawing up.
c. upsetting.
d. heading.

4. To form sheet-metal seams and get into tight corners, it is advantageous to use a __________ type hammer.

a. ball peen
b. cross peen
c. set
d. wooden mallet

5. To "burktail" a rivet means that you are

a. cutting the rivet shank.
b. drawing the rivet.
c. heading the rivet.
d. smoothing the rivet's edges.

6. List the four catagories of special tools used in metal-working.

a.
b.
c.
d.

LIST THE EIGHT MACHINES USED TO FORM SHEET-METAL.

a. Slip-roll forming machine (fig 4-17). Sheet metal can be formed into curved shapes over a pipe or mandrel, but the slip-roll forming machine is much easier to use and produces more accurate bends. Rolling machines are available in different sizes and capacities; some are hand-operated, others are power-operated. The machine in figure 4-17 has two rolls at the front and one roll at the rear. Adjusting screws on each end of the machine adjust the height and angle of the rear roll and control the distance between the front rolls. By adjusting the rolls, the machine can be used to form cylinders, cones, and other curved shapes. The front rolls grip the metal and pull it into the machine; therefore, the adjustment of distance between the front two rolls is made on the basis of the thickness of the sheet being used. Conical shapes can be formed by setting the back roll at an angle before running the sheet through it, or they can be made with the rolls parallel. To make a cone with the rolls parallel involves slipping the large end of the cone through the rolls at a slightly faster rate than the small end of the cone. Grooves located at the end of the rolls are used for rolling wire or rods. To form a cylindrical object as shown in figure 4-17, the rolls must be parallel to one another. The front rolls grip the metal and pull it into the machine. These rolls are geared to the operating handle and must be adjusted so that just enough pressure is exerted on the sheet to enable the machine to "grab" the metal. The rear roll is an idler and is adjusted up or down to form the desired radius. Adjust the front rolls to grip the metal that you are forming. Adjust the rear roll to a height that is obviously less than enough to form the desired radius of the cylinder being formed. Start the sheet into the roll. As soon as the front rolls have gripped the sheet, raise the free end slightly. Pass the entire sheet through the rolls, forming a partial curve of the cylinder. Set the rear rolls higher to form a shorter radius, turn the sheet end for end, and pass it through the rolls. Continue turning the sheet end for end, adjusting the rear rolls, and passing the sheet through until the desired radius is formed. To facilitate the removal of cylinders from the rolls, the top front roll has a releasing device by which you can release and raise one end of the roll to slip off the work. Practice and experience will enable you to adjust the rear roll for any desired radius.

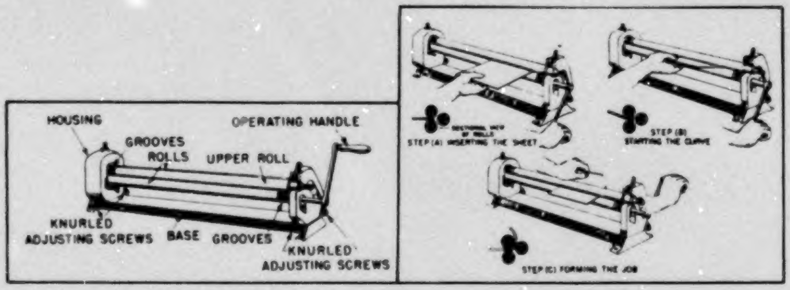


Fig 4-17. Forming a cylinder with slip-roll forming machine.

b. Rotary machine (fig 4-18). This is used on cylindrical and flat sheet metal to shape the edge or form a bead along the edge. Various-shaped rolls can be used to perform operations such as beading, turning, wiring, crimping, and burring. The beading rolls are used for turning beads (grooves) on such items as tubing, cans, and buckets, and for stiffening and gripping. Beads may also be placed on sheet stock that is to be welded. Turning rolls are used for turning an edge to receive a stiffening wire. The wiring rolls are used to finish the wired edges prepared on the turning rolls. Crimping rolls are used to make one end of a pipe smaller, so that two sections may be joined together by slipping the crimped end into the uncrimped one. To turn an edge at right angles to form burrs (narrow flanges) for seams or hems, adjust and aline the rolls so that the inside edge of the top roll fits over the shoulder of the bottom roll. Make the clearance equal to the thickness of the metal. This is important as less clearance will cause the top roll to act as a shear and damage your material. Set the gage to turn up the proper amount of metal. This is usually from 1/8 to 3/16 inch. Place the disk as shown in figure 4-19A and move the top roll down until it grips the stock and creases it slightly. Crank the handle, keeping the edge of the disk against the gage. Allow the disk to revolve as you crank (fig 4-19B). The first revolution should be fairly slow so you can get the burr accurately established. After the first revolution of the disk, disregard the gage and follow the crease, increasing the top roll pressure and turning as before. Raise the disk slightly after each revolution (fig 4-19C), and you can increase your cranking speed. The rotary head will take sets of rolls which are attached to the shafts by round nuts that screw flush with the outside of the rolls. Figure 4-20 shows a set of wiring rolls being used to wire an edge. Always double check your machine setup by doing a practice job on a piece of scrap metal first. This will save you a lot of trouble as well as a lot of material.

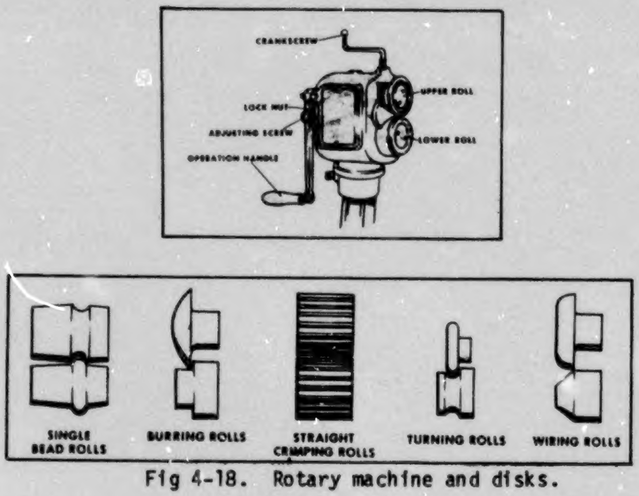

CRANKSCREW
UPPER ROLL
LOCK NUT
ADJUSTING SCREW
LOWER ROLL
OPERATION HANDLE
SINGLE BEAD ROLLS
BURRING ROLLS
STRAIGHT CRIMPING ROLLS
TURNING ROLLS
WIRING ROLLS

Fig 4-18. Rotary machine and disks.

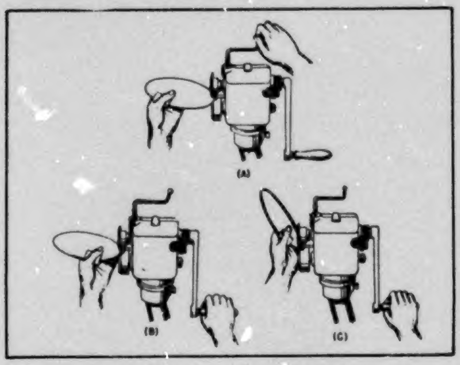


Fig 4-19. Burring a disk.

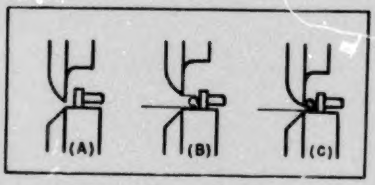


Fig 4-20. Wiring an edge.

c. Cornice brake (fig 4-21). The cornice brake is designed for bending large sheets of metal. It is adjustable for clamping a wide variety of metal thicknesses and for bending this metal to a variety of radii. The brake is equipped with a stop gage consisting of a rod, yoke, and setscrew, by means of which the travel of the bending leaf is limited. This is a useful feature when it is necessary to make a number of pieces with the same angle of bend. The standard cornice brake is extremely useful for making single hems, double hems, lock seams, and various other shapes, some of which require the use of molds. The molds are

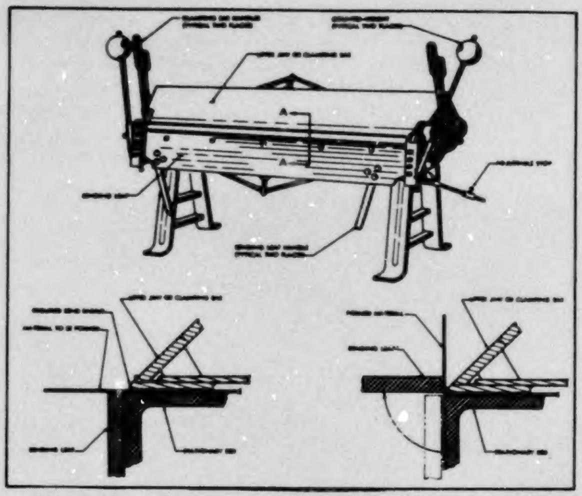


Fig 4-21. Cornice brake and bending operation.

fastened to the bending leaf of the brake by friction clamps, in such a position that the work can be formed over them. This machine is ruggedly constructed and will give lifetime service if used properly. It will speed up your work and produce more uniform bends than can be produced by hand. Before making bends with the cornice brakes, there are two things you have to do in addition to making sure that the metal you are working with is not beyond the rated capacity of the brake; they are as follows:

> Adjust the clamping adjustment screw for the gage metal you are working. The clamping device holds the work firmly in position.
>
> Adjust the upper leaf to at least the thickness of the metal. The distance is measured from the front edge of the lower jaw to the front edge of the upper jaw.

It is important that you make these adjustments. For example, if your clamping adjustments are set for 18-gage metal and you make a bend in 24-gage metal, your sheet will not be held firmly in position and will slip. This usually causes the bend to show up in the wrong place. On the other hand if the brake is adjusted to clamp a very thin piece of sheet metal and a thick sheet is inserted, the strain exerted on the clamping handle may be enough to break it. To use the cornice brake, select a piece of 18-gage or 20-gage scrap metal. Scribe a line across the surface (this line is known as the bend or brake line). Set the clamping jaw device so that the metal will be held firmly in place without having to exert too much pressure on the clamping handle. Set the bend allowance (fig 4-22) on the upper leaf for the metal you are working on. This distance is measured from the front edge of the bottom leaf to the front edge of the upper jaw. When the allowance set on the upper jaw is equal to the thickness of the metal, you will get a sharp bend. When your allowance is greater than the metal thickness, the bend will have a slight arc. Raise the upper leaf with the clamping handle and insert the sheet into the brake, bringing the scribe line on the sheet into a

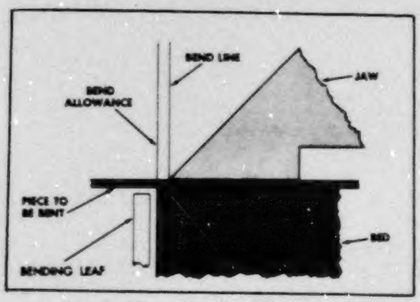


Fig 4-22. Bend allowance.

position even with the front edge of the upper jaw. Clamp the sheet firmly into position. Raise the lower leaf to the desired angle to form the bend or flange. Release the clamping device and remove the sheet from the brake. When the metal you bend is soft and ductile, your bend will stay put. If the metal is hard and springy, you will have to raise the lower leaf a few more degrees than you would for soft metal to commpensate for the spring back of the harder metal. The exact amount will be determined by the metal. Experience will be your instructor and your eye will be your guide. You will sometimes have to make bends of the same degree in a large number of pieces. When you have made the first bend, set the stop gage. To do this, raise the bending leaf to the position required to make the first bend, slide the yoke (fig 4-21) up the rod until it touches the stop through which the rod passes, and tighten the setscrew. You can now make duplicate bends by raising the leaf until it contacts the stop gage.

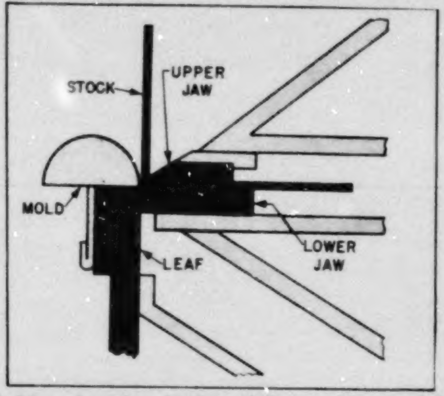


Fig 4-23. Cornice brake with attached mold.

d. Box and pan brake (fig 4-24). The box and pan brake is often called the finger brake since it does not have solid upper jaws as does the cornice brake, but a series of steel fingers of varying widths. The finger brake can do everything that a cornice brake can do and several things that it can not do. The fingers are secured to the upper leaf by thumbscrews. All fingers which are not removed for any operation must be securely seated and firmly tightened before the brake is used. The finger brake is particularly useful for forming boxes and similar objects. If a box were to be formed on a cornice brake, it would be necessary to partially straighten one side of the box in order to complete the job. On the finger brake, it is only necessary to remove the fingers that are in the way. The finger brake is operated in the same manner as the cornice brake. Before you start any work on the finger brake, be sure that all the adjustments are correctly made for the gage metal that you are going to form, and that all fingers are properly set up. These fingers can be easily sprung if the machine is misused or improperly adjusted. Don't bend rod, wire, band iron, or spring tempered steel sheets on either the cornice or finger brake.

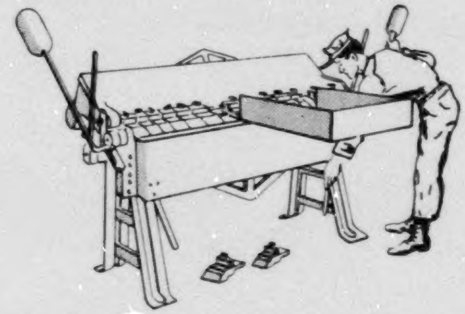


Fig 4-24. Box and pan brake being used to form box.

e. Bar folder (fig 4-25). The bar folder is a bench-mounted machine used to fold and bend metal in a number of shapes. It is equipped with a graduated scale to obtain any desired seam widths up to 1 inch. An adjustable collar stop allows the folder to be set so that any bend angle can be made. An adjusting screw located on the back of the machine controls the raising or lowering of the wing, which in turn gives the desired sharpness of the bend. To operate the bar folder, adjust the thumbscrew to the specified width of the fold, then turn the wing-adjusting screw on the back of the machine for the desired sharpness of the bend. Insert the metal under the folding blade until it rests against the stops. Hold the metal firmly in place with one hand, grasp the handle with the other, and pull forward until the desired fold is made.

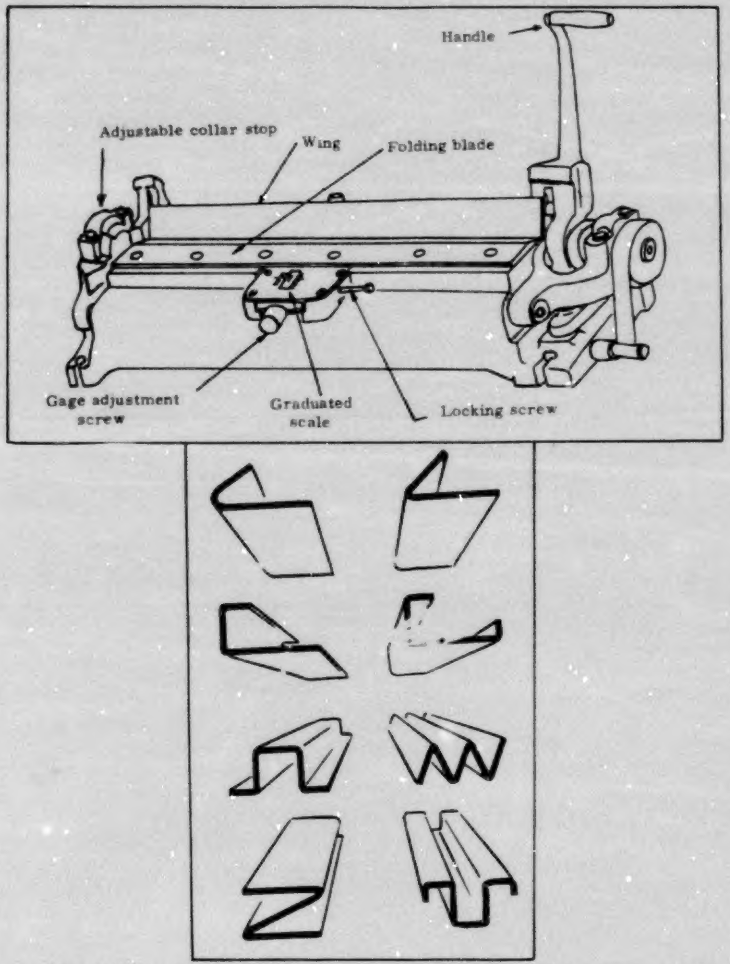


Fig 4-25. Bar folder and types of bends which can be made.

f. Deep-throated beading machine (fig 4-26). Although beading may be done in an emergency with the turning rolls of the rotary machine, the deep-throated beading machine is especially designed for this. You will need to take several revolutions to form a bead, thus avoiding severe stresses and possible cracks. Start beading next to the seam and stop just before the seam is reached. Never allow a seam to pass through the rolls. If the thick seam goes through the rolls, it will spring the machine and weaken the seam.

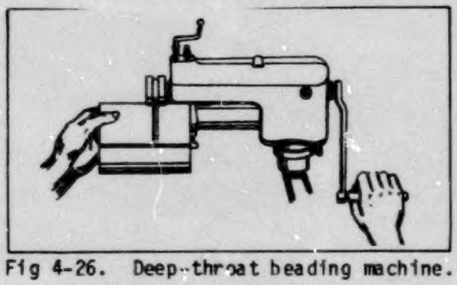


Fig 4-26. Deep-throat beading machine.

g. Crimping machine (fig 4-27). Crimping machines are used to shrink (by corrugation) the ends of metal cylinders so they can be fitted into other cylinders of the same size. Some machines also carry beading rolls next to the crimping rolls as shown in the illustration. The bead reinforces the cylinder and prevents it from slipping too far into other cylinder.

For jobs with riveted or grooved seams, start the crimp near the seam and stop the crimp near the seam and stop the crimp when it comes around to the seam. Never crimp over a seam; it will damage the rolls and spring the shafts. Keep the edge of the cylinder against the gage and you will get a neat job.

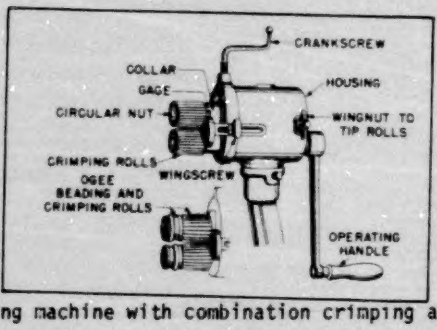


Fig 4-27. Crimping machine with combination crimping and beading rolls.

h. Setting down machine (fig 4-28). Setting down machines are used to close single seams. They are a 1-job machine, that is, they can be used only for setting down or closing seams. Their beveled jaws grip the seam and mash it down to make it tight and smooth.

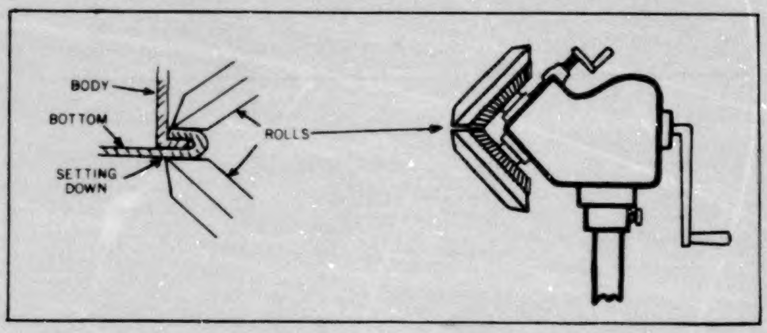


Fig 4-28. Setting down machine closing a seam.

i. Sheet-metal stakes (fig 4-29). Some of the work that you may do in a sheet-metal shop may involve the use of anvils and stakes. You may not have all of those illustrated in figure 3-29, but you will probably have some of them. These stakes have a variety of shapes and are used to back up the metal when forming the many curves, angles, and seams in the forming process. The stakes are not delicate instruments and many of their faces are hardened steel; nevertheless, they demand proper care and use. Do not use them as backing when chiseling holes or notches in sheet metal. If they are used in this manner, their surfaces will become marred. Some of your work may require the use of several stakes. The stake is held securely in a stake holder which is usually anchored to a workbench. One of the tappered holes in the stake plate will fit the tapered shank of the stake that you may be using. Small, cylindrical shapes and bends with small radii can be formed over the stakes. Suppose you were told to form a small cone over a stake. Figures 4-30 and 4-31 illustrate the forming of a cone on a blowhorn by light blows with a mallet. Form the remaining portion of the cone with your hands by working the sheet with a rolling, sliding motion over the stake. When selecting the stake, remember that the radius of the stake must be slightly smaller than the radius of the object that you are forming. Form the edges of the sheet in the manner you used on the cone, and finish the operation with your hands. If the material you are forming is a heavier gage than you can readily work with your hands, you will have to form the piece over the stake using a mallet to shape the sheet.

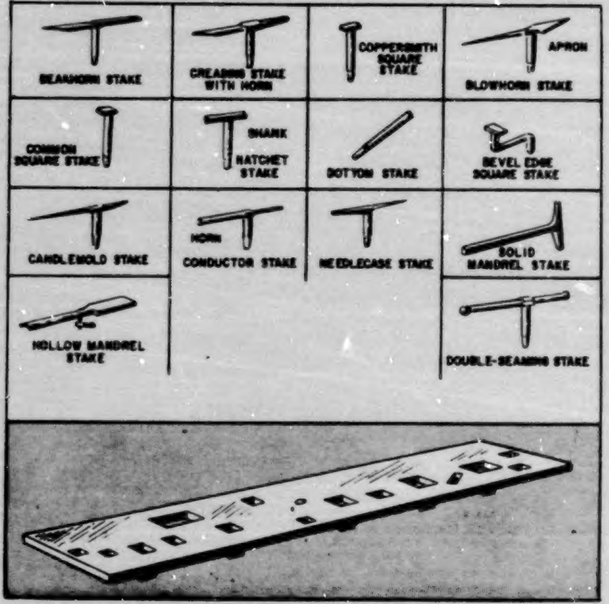

BEAKHORN STAKE
CREASING STAKE WITH HORN
COPPERSMITH SQUARE STAKE
APRON
BLOWHORN STAKE
COMMON SQUARE STAKE
SHANK
HATCHET STAKE
BOTTOM STAKE
BEVEL EDGE SQUARE STAKE
CANDLEMOLD STAKE
HORN
CONDUCTOR STAKE
NEEDLECASE STAKE
SOLID MANDREL STAKE
HOLLOW MANDREL STAKE
DOUBLE-SEAMING STAKE

Fig 4-29. Stakes and stake plate.

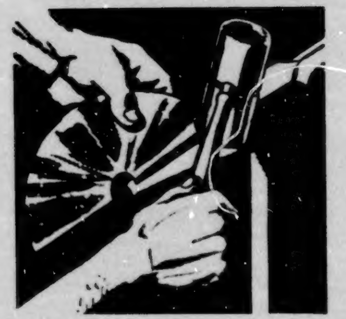


Fig 4-30. Forming a cone on a blowhorn stake.

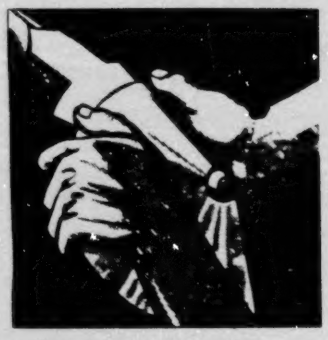


Fig 4-31. Forming a cone with your hands.

j. Summary. Shop organization varies from one duty station to another. A relatively large repair facility may be organized to permit a great deal of specialization, that is, some metalworkers will work as sheet-metal men, others may devote all their time to welding. In smaller units, you may work on different jobs without specialization in any of them. It is likely that you will be assigned first to one type of unit and then to another; not only will you do different types of work, but you will be working with different types of machinery. Although you may not know the proper methods of operating these machines, your NCOIC will give you the scoop on the how's, why's, and wherefore's. It was the intent of these paragraphs to familarize you with the different types of machines and practices that you may encounter in your travels about the Corps. The most important things to remember about tools (personal, special, or shop) are to use them for the purpose for which they are intended, keep them clean, and keep them in topnotch condition.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. When forming a cylinder on the slip-roll forming machine, you obtain the desired radius by adjusting the _________ roll(s).

   a. top front
   b. lower front
   c. two front
   d. rear

2. Conical shapes can be formed on the slip-roll machine by angular setting of the __________ roll(s).

   a. rear
   b. top front and rear
   c. two front
   d. bottom front and rear

3. The process in which a machine turns an edge at right angles to form narrow flanges for seams is known as

   a. beading.
   b. burring.
   c. turning.
   d. crimping.

4. The process whereby rounded edges are formed is called

   a. burring.
   b. beading.
   c. turning.
   d. wiring.

5. The process of shrinking the end of a metal cylinder so that it can be fitted into a cylinder having the same diameter is known as

   a. setting down.
   b. drawing.
   c. grooving.
   d. crimping.

6. A machine used to make a uniform bend in sheet metal is called a

   a. cornice brake.
   b. bender.
   c. bending stake.
   d. creasing stake.

7. A bend, made with a cornice brake, that has a slight arc indicates a jaw setting that is

   a. equal to the thickness of the metal.
   b. less than the thickness of the metal.
   c. greater than the thickness of the metal.
   d. twice as large as the thickness of the metal.

8. Spring-back allowance for machine bending of hard and springy metal is compensated for by

   a. increasing the machine pressure.
   b. annealing the metal before bending.
   c. raising the lower leaf a few more degrees than you would for softer metal.
   d. adding the difference between the inside and outside radius of the bend to the thickness of the metal

9. To make duplicate machine bends you would use a

   a. stop gage.
   b. dolly.
   c. stake.
   d. finger.

10. A machine in which parts of the upper leaf may be removed for forming a box is called a

    a. cornice brake.
    b. finger brake.
    c. bar folder.
    d. mold.

11. On the bar folder, the desired sharpness in the bend is obtained by setting the

    a. graduated scale.
    b. gage adjustment screw.
    c. adjustable collar stop.
    d. wing-adjusting screw.

12. When using the crimping machine with rolls and encountering a seam in the metal, you should

    a. permit it to go through the rolls with reduced pressure.
    b. never form it until after crimping.
    c. never permit it to go through the rolls.
    d. permit it to go through the rolls one time only.

13. The mashing down of a single seam to make it smooth and tight is called

a. drawing.
b. crimping.
c. setting down.
d. upsetting.

14. Bend lines on sheet-metal are sometimes referred to as _________ lines.

a. drawing
b. brake
c. center
d. protection

15. When selecting a stake, you should select one whose radius is _________ the object being formed.

a. slightly larger than
b. slightly smaller than
c. the same size as
d. one-half as large as

16. List the eight types of machines used in metalworking.

a.
b.
c.
d.
e.
f.
g.
h.

Work Unit 4-4. SHEET-METAL LAYOUT

IDENTIFY THE BASIC PROCEDURES AND FUNDEMENTALS OF SHEET-METAL LAYOUTS.

Before laying out jobs on sheet metal, you would save material if you would first practice the layout on paper. If at all possible, use template paper. This material has a waxed surface that is well adapted to scribe and divider marks; however, if none is available, heavy brown wrapping paper can be substituted. In this case a hard pencil will have to be substituted for the scriber, and a pencil divider for your layout dividers. Care should be taken to keep your pencils, dividers, and scribe sharp because the accuracy of your work will depend on them.

a. Using layout tools.

(1) Scribing a line. Figure 4-32 illustrates the correct method of scribing a line using a scriber and rule. Hold the scale or straightedge firmly in place. Set the scriber as close as possible to the edge of the scale by tilting it outboard. Exert pressure on the point and draw the line, tilting the tool slightly in the direction of movement. When you have to draw a line between two points, prick-punch both points, and start from one mark and scribe toward the center; then complete the line by scribing from the other mark to join the first line.

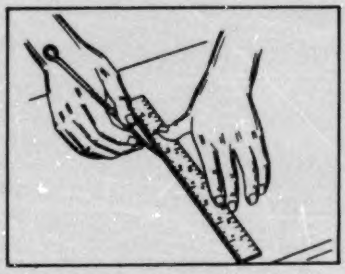


Fig 4-32. Scribing a line.

(2) Steel square. The flat steel square is a useful tool for laying out sheet-metal jobs. Before using it, or at least at periodic intervals, you should check the square for accuracy. When your square is off, your work will be off no matter how careful you are. In parallel line development, you will use the square to construct lines that are parallel to each other as well as perpendicular to the base. This procedure is illustrated in fig 4-33. Just clamp the straightedge firmly to the base line, slide the body of the square along the straightedge, and draw perpendicular lines through the desired points.

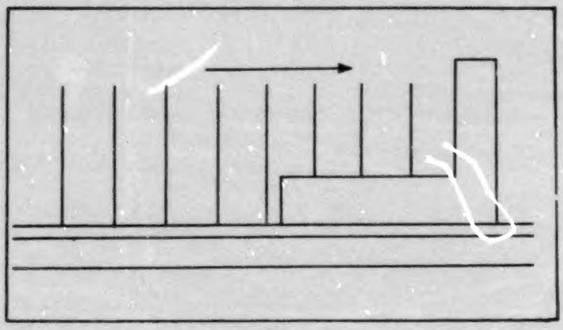


Fig 4-33. Drawing parallel perpendicular lines.

(3) Combination square and protractor. The combination square can be used to draw a similar set of lines as shown in figure 4-34. An edge of the metal upon which you are working is used as the base line in both cases. One edge of the head of the combination square is 90° and the other is 45°. With the square you can construct 45° and 90° angles, but how about lines at angles other than 45° and 90°? The protractor is the tool you need. Mark the vertex of the angle on your base line with a prick punch (fig 4-35). The vertex is the termination or intersection of lines. set the vertex of your protractor on the mark and then scribe a small V at the desired angle. Scribe a line from the V mark to the vertex mark and you have constructed an angle. When you locate a point and mark it with the prick punch, use very light taps with a small ballpeen hammer. The smaller the mark you make, the more accurate that mark becomes.

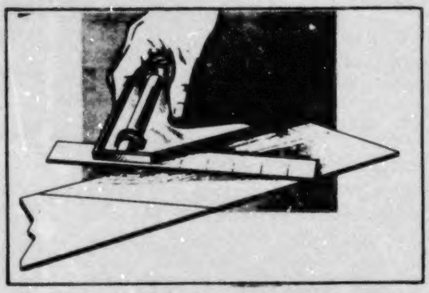


Fig 4-34. Using combination square.

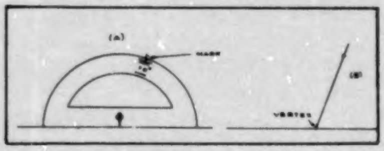


Fig 4-35. Angle construction with protractor.

(4) Dividers. You will use dividers to scribe arcs and circles, to transfer measurements from a scale to your layout, and to transfer measurements from one part of the layout to another. Careful setting of the dividers is of prime importance. When you transfer a measurement from a scale to the work, set one point of your dividers on the mark, adjust the other leg to the desired length, and tighten the lock screw securely. To scribe an arc, or a circle, grasp the dividers between the fingers and thumb, place the point of one leg on the center and, exerting enough pressure to hold the point on center, slightly incline the dividers in the direction in which they are being rotated, and swing the arc.

(5) Trammel points. There will be times when you will have to construct circles or arcs larger than the dividers are capable of making. This is when you will use the trammel. To adjust the trammel points, you set the left leg on the mark, slide the right leg along the beam, and tighten the thumbscrew. The arc or circle is then scribed in the same manner as with the dividers.

b. *Simple layouts.* A stretchout is a pattern on a flat sheet which has not been formed. If a flat sheet is laid out to the correct shape and size, it may be formed into a 3-dimensional object (fig 4-36). When jobs are laid out, allowances for edges and seams must be added. There are many different ways to lay out patterns on flat sheet metal. Here we will discuss some of the methods that you may use in most metalworking layouts using the tools previously mentioned.

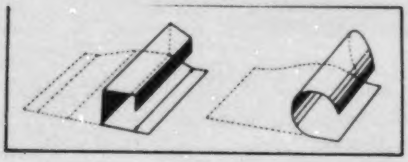


Fig 4-36. Forming square and cylindrical shapes from flat patterns.

(1) *Geometric construction.*

(a) *Erecting a perpendicular and bisecting a line.* This is no trick at all if you have a true steel square. But suppose you have on square and you still need a right angle for your layout. Break out your dividers, a straightedge, and a scriber. Draw a base line like the one labeled AB in figure 4-37. Set your dividers for a distance greater than 1/2 AB, then with A as the center, scribe arcs at C and D. Then without changing the setting on your dividers and using B as a center, scribe another pair of arcs at C and D. Draw a line through the points where the arcs intersect and you will have erected prependiculars to line AB, forming four 90° angles. You will also have bisected line AB into two equal parts.

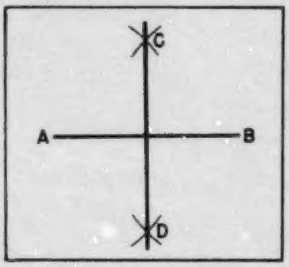


Fig 4-37. Bisecting a line.

(b) *Construction of a 90o angle with dividers.* Constructing a right angle at a given point with a pair of dividers is something you will find quite useful in making layouts. Figure 4-38 illustrates a method for constructing a right angle at a given point. Suppose you have line XY with A as a point at which you need to construct a right angle. Select a point within the proposed angle that you wish to construct. In figure 4-38, that point is C. Set your dividers equal to CA, and using that as a radius, swing an arc BAD with C as the center. Lay a straightedge along the points D and C and draw a line which will intersect the arc at B. Now draw a line connecting points A and D and you have constructed a 90° angle. This method may be used for constructing corners in a stretchout for square or rectangular objects.

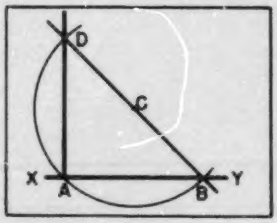


Fig 4-38. Constructing a 90° angle at a give point.

(c) Bisecting an angle (fig 4-39). Another construction that you should be familiar with is bisecting an angle. Referring to the illustration we find the angle ABC is given. With B as the center, draw an arc cutting the sides of the angle at D and E. With D and E as centers, set your dividers with a radius greater than half of arc DE and draw arcs intersecting at F. A line drawn from B through the point at F bisects the angle ABC. In all probability you will have a protractor to lay out angles, but just in case you don't have a square or protractor, it's a good idea to know how to construct angles of various sizes.

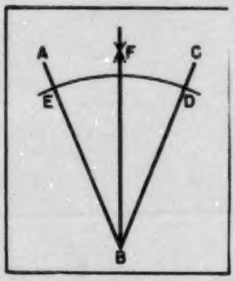


Fig 4-39. Bisecting an angle.

(2) Cylindrical layout (fig 3-40). The stretchout of a cylindrical object will be rectangular in shape. One dimension of the layout will be the circumference of the cylinder. When you are given dimensions for a cylindrical job, you will be given the diameter of the finished product rather than the circumference. This you will have to find out for yourself. There are two ways for you to do this, by computation or by using a circumference rule. Remember that the circumference of any circle is 3.1416 (π) times the diameter ($C=\pi D$). By using this formula you can find the length of the stretchout of any cylinder. The length of the desired cylinder is your other dimension. Another method is by the use of the circumference rule (fig 3-41). The upper edge of the rule is graduated in inches in the same manner as your regular scale, but the lower edge is graduated in circumference inches. That is, no matter what diameter in inches you select on the upper edge, the reading directly below that is 3.1416 times the top reading.

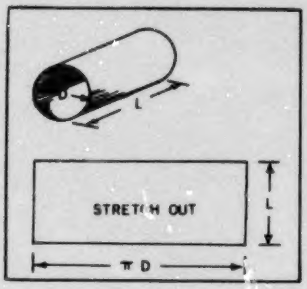


Fig 4-40. Stretchout of a cylinder.

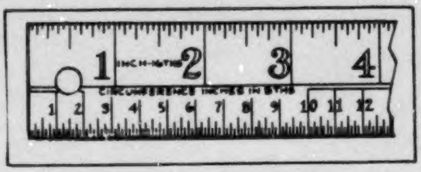


Fig 4-41. Circumference rule.

Notice in figure 4-1 that the reading directly below the 3 1/2-in. mark is just a shade over 11 inches. This reading would be the length of the stretchout of a cylinder of that diameter. A variation of the cylindrical job that you may run into is a flat-sided figure with round ends (fig 4-42). To figure the stretchout for this shape, find the circumference of a complete circle that would be formed by the two curved ends of the shape. Then add twice the length of the straight part, W in figure 3-42. Use the following formula for figuring your unknown dimensions: Stretchout $= \pi D + 2W$. The symbol π is always 3.1416. Here is an example: Let D = 5 and W = 6. Now, $3.1416 \times 5 + 2 \times 6 = 27.7080$, or about 27 3/4 inches. So one side of your stretchout would be 27 3/4 inches and the other, of course, would be the length of the cylinder.

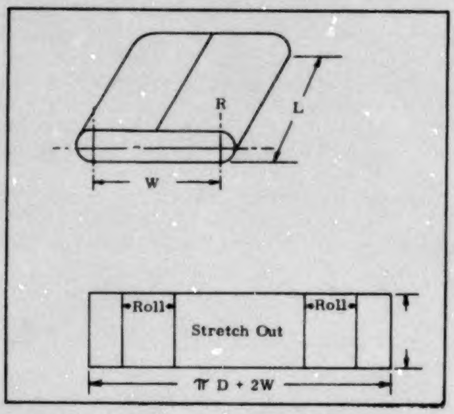


Fig 4-42. Cylindrical variation.

(3) Pattern development. Before we progress to other methods of laying out patterns, let us lay out a simple drip pan of the type that may be found in any shop using some of the methods that we have covered up until now. First you will need dividers, a straightedge, and a sheet of paper. For this exercise you can form your own dimensions: the length, width, and height of the pan. Draw a base line (line AB, fig 4-43). Select a point on this line for one corner of your layout. Erect a perpendicular through this point to form a 90° angle. Now, measure off the required length of the pan and erect another 90° perpendicular line. You now have three sides of your layout. Using the required width of your pan for the other dimension, connect the two perpendiculars that you have erected. Now, set your dividers for marking off the depth of the pan. Using each corner for a center, swing an arc as shown in the illustration. Extend the end and side lines as shown in the last step of figure 4-43, and complete the stretchout by connecting the arcs with the straightedge and scriber. All that is left to do is to allow for seams, which will be discussed later, transfer of the pattern to sheet metal, and cutting it and bending it. You have seen how to lay out a drip pan without a steel square by the use of geometric construction. You bisected a line, erected a perpendicular from a given point, and drew parallel lines. You will find that these and other geometric principles may be used to do a lot of layout problems rapidly.

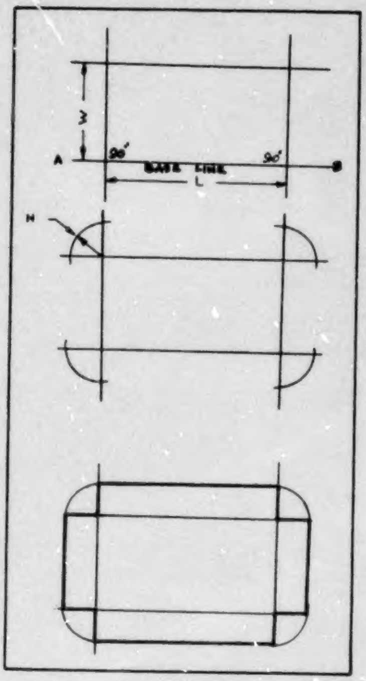


Fig 4-43. Layout of a drip pan.

(4) Parallel, radial line pattern development. If the only work you would be called on to do consisted of laying out and fabricating drip pans, boxes, and straight sections of cylindrical and retangular objects with straight lines, your work would be easy since it would consist of nothing but straight-line angular development, plus allowances for seams and edges, and visualizing the notch needed. But there may come a time when work will call for elbows and tees which cannot be laid out with the straight-line method.

(a) Parallel line. This development is based on the fact that a line parallel to another line is an equal distance from that line at all points. The main lines of a structure to be laid out by parallel line development are parallel to each other. Objects having opposite lines parallel to each other, or which have the same cross-sectional shape throughout their length, are developed by this method. In doing this, there are certain procedures that must be followed:

First, draw a plan and elevation of desired object in which the parallel lines are shown in their true lengths.

Visualize the pattern from a right view of the object in which the miter or lines of intersection are shown (fig 4-44A).

Draw a stretchout at right angles to the parallel lines of the object, upon which is placed each space contained in the section or plan view (fig 4-44B).

Draw measuring lines at right angles to the stretchout lines of the pattern.

Draw lines from the points of intersection on the miter line (fig 4-44C) and extend these lines to intersect similarly numbered lines drawn from the stretchout, to show the outline of the development.

Trace a line through the points thus obtained to give the desired pattern.

Hard to understand? All right, let's construct or develop step by step a layout of a vent pipe by the parallel line method. Such a pipe may be used for ventilation of a building. First, construct an elevation on the miter line similar to the one in figure 4-44A. The miter line is inclined plane or slant of the roof line CD. The elevation is a front view. Line AB represents the diameter of the pipe. The distance between line AB and the miter line is the height of the pipe, which will vary around the circumference of the pipe. Find the center of line AB and construct a centerline as shown in figure 4-44A. Set your dividers for one-half the distance of line AB. Construct line 1-7 parallel to and just above line AB. Using the point where line 1-7 is intersected by the elevation center-line, swing an arc with the dividers, completing the half plan as shown in figure 4-44A. Step off the circumference of your half plan with your dividers into six equal parts by taking 1/2 the radius and starting at point 1 making an intersecting arc at point 2. Then set your dividers at point 2. Make another intersecting arc at point 3 and continue around the circumference of the half plan until it is equally divided as shown in figure 4-44B. Set your straightedge at right angles to the centerline and, using it as a base line, draw lines parallel to the center-line. These parallel lines must be drawn from the points where the arcs intersected the circumference of the half plan to the miter line. With your straightedge, draw line EF (an extension of line AB), and step off twice the distance you stepped off in the circumference of the half plan. Draw a line GH parallel to EF at a distance equal to the greatest height of the elevation. Through the points located on the extended line EF, by stepping off with your dividers, connect lines Ef and GH by drawing parallel lines and number these lines in proper order as illustrated (1 to 7 to 1). You are now set to transfer the miter line KDC in the elevation to the elevation to the stretchout. To transfer the miter line, merely project the points of intersection on the miter like-numbered lines on the stretchout (indicated by long broken lines). These lines are drawn at right angles to the numbered lines and parallel to line AB. They are drawn from the point at which they intersect the most distant like-numbered line in the stretchout. The pattern is completed by connecting the points of intersection on the stretchout with a curved line (indicated by small broken lines in figure 4-44C). Remember, the more care you take in drawing your elevation, stepping off the half plan, and transferring your measurements, the more accurate the finished product will be.

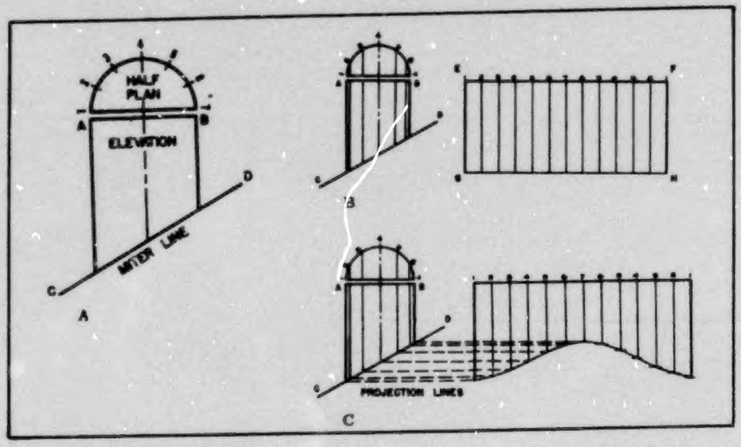


Fig 4-44. Elevation and plan of intersected pipe.

(b) Radial line. This method of pattern development employs some of the features of the parallel line development that you will recognize when you have laid out a frustum of a right cone. You are familiar with a cone. A right cone is one which, if set on a flat surface, would stand straight up. The frustum of a cone is that part which remains after the point, or top of the cone is removed. To develop a pattern for the frustum of a cone, let's proceed on a step-by-step basis referring to figure 4-45.

1 Draw a side view of the cone, using such dimensions as the job may require. Letter the vertex A and the base BC. At point D, and parallel to line BC, draw a line that cuts the top of the cone. That portion below this line is the frustum.

2 Draw the half plan beneath the base of the frustum. Step it off into an equal number of spaces and number as illustrated.

3 Set your dividers the length of the cone along line AC and, using the vertex A, swing an arc equal to the length of the circumference of the bottom of the cone ($C = \pi D$).

4 Set your dividers equal to the distance of the step-offs on your half plan and step off twice as many spaces as there are in the half plan. Number them 1 to 7 to 1.

5 Draw lines connecting A with point 1 at each end of the stretchout.

6 Now with A for a center, set your dividers along line AC to the length of AD. Scribe an arc through both lines drawn from A to 1. The area enclosed between the large and small arcs and the line numbered 1 is the pattern for the frustum of a cone. Add allowances for seams and edging and your stretchout is complete.

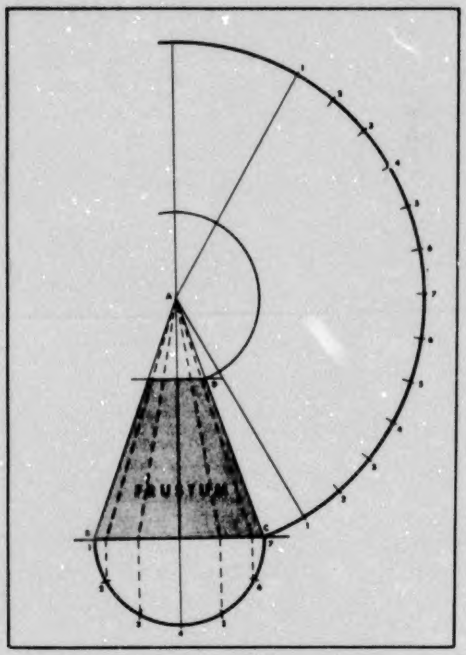


Fig 4-45. Radial development of a frustum of a right cone.

(5) Edges, seams, and notches. Thus far your practice jobs have been laid out to be formed with the edges left as they are. Very few jobs in the shop will actually be fabricated in this manner. Edges are formed to improve the appearance of the work, strengthen the piece, or to eliminate the raw edge. These edges may be formed from the metal itself, by inserting wire, or by attaching a band or angle iron. The kind of edge that you will use on any job will be determined by the purpose, size, and/or strength of the edge needed.

(a) Edges (fig 4-46). The single-hem edge can be made of any width. In general, the heavier the metal, the wider the hem. The allowance for the hem is equal to its width (W in the illustration). The double-hem edge is used if additional strength is required or if a smooth edge is desired inside as well as outside. The hem allowance is double the width of the hem. A wired edge will often be specified in the plans. Objects such as ice cube trays, funnels, and water buckets are manufactured with wire edges to strengthen and stiffen them and to eliminate sharp edges. The allowance for a wired edge is 2 1/2 times the diameter of the wire being used.

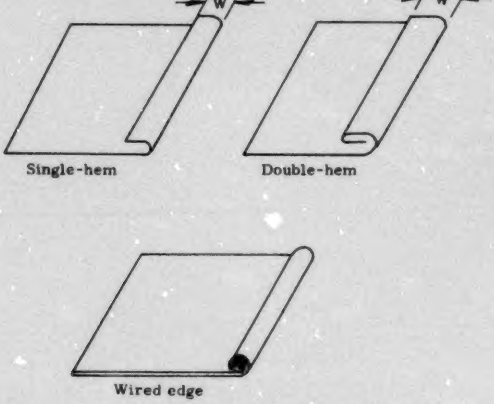


Fig 4-46. Types of edges.

(b) Sheet-metal seams.

1 Lap seams (fig 4-47). During the instruction on laying out a drip pan, it was mentioned to allow for tabs for seaming with rivets. This method of joining sheet-metal is known as lap seaming. Lap seams may be plain, offset, or corner lap. These seams may be joined by drilling and riveting, soldering, or a combination of both. To figure the allowance for seams that you plan on riveting, you must know the diameter of the rivet to be used. The center of the rivet must be set in from the edge a distance 2 times its diameter. Your allowance for the seam, then, must be 4 times the diameter of the rivet to be used. Figure 4-47 illustrates lap seams and plain lap and corner lap layouts for seaming with rivets. On the corner lap, allow an additional 1/16 in. for clearance. The "d" represents the diameter of the rivet.

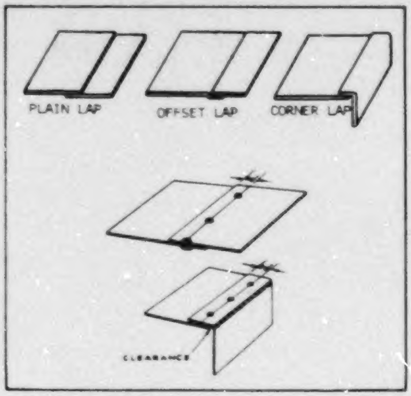


Fig 4-47. Lap seams and riveting layout.

2 Grooved seams (fig 4-48). These are useful in construction of cylindrical objects. The two types are the inside groove and the outside groove. The allowance for a grooved seam is 3 times the width (W in fig 4-48) of the lock, one-half of this amount being added to each edge. For example, if you have a 1/4-in. grooved seam on completion of the seam, then you must allow 3 times this amount (3 x 1/4 = 3/4 in.) for the total allowance of material needed to complete the seam. The amount of material that you add to each end of the sheet metal for this seam is 1/2 of the total amount, or 3/4 x 1/2 = 3/8 in.

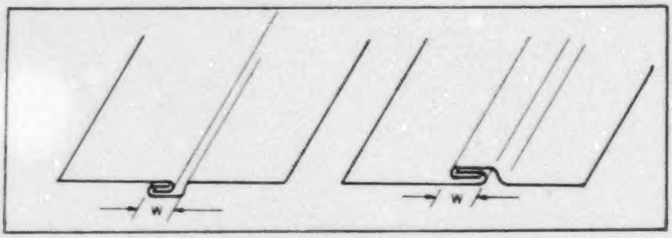


Fig 4-48. Grooved seams.

3 Pittsburgh lock seam (fig 4-49). This is a very useful corner seam which is used to advantage in the fabrication of rectangular ventilation lines, elbows, and boxes. At first glance, the seam appears to be rather complicated, but like lap and grooved seams, it consists of only two pieces. The two parts are the flanged or single edge and the pocket that forms the lock. The pocket is formed, the flanged edge is inserted into the pocket, and the projected edge is turned over the inserted flanged edge. The allowance for the pocket is W + W + 3/16 inch. The flanged edge must be less than W. For example, if you are laying out a 1/4-in. Pittsburgh lock, your total allowance should be 1/4 + 1/4 + 3/16, or 11/16 in. for the pocket edge and 3/16 in. for the flanged edge.

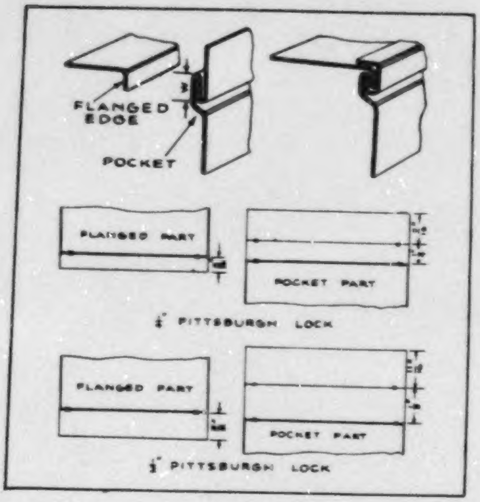

FLANGED EDGE
POCKET
FLANGED PART
POCKET PART
PITTSBURGH LOCK
FLANGED PART
POCKET PART
PITTSBURGH LOCK

Fig 4-49. Layout of Pittsburgh lock seams.

(c) Notch construction (fig 4-50). Notching is the last, but not the least, important step to be considered when you are getting ready to lay out a project. Before you can mark a notch, you will have to lay out a pattern and add the seams, laps, or stiffening edges. If the patterns aren't properly notched, you will have trouble when you start forming, assembling, and finishing the job. No rule for selecting the proper notch for the job can be given. But as soon as you get to where you can visualize the assembly of the project, you won't have any trouble determining what type of notch will be needed. If the notch is too small, or not the proper shape, the metal will bulge and overlap at the seam or edge. If the notch is too large, a hole will appear in the final job. Don't worry if the first notch you make doesn't look well or come out as you would like it to. This comes with practice and experience. One of the first that you will probably make is the slant notch. It is cut at a 45° angle across the corner when a single hem is to meet at a 90° angle. When you are seaming the ends of boxes, trays, pans, etc., a V-notch is used. Figure 4-50 shows the step-by-step method of constructing a V-notch. If, however, you are going to make an inside flange on an angle less than 90°, you will have to construct a modified V-notch in order to get flush joints.

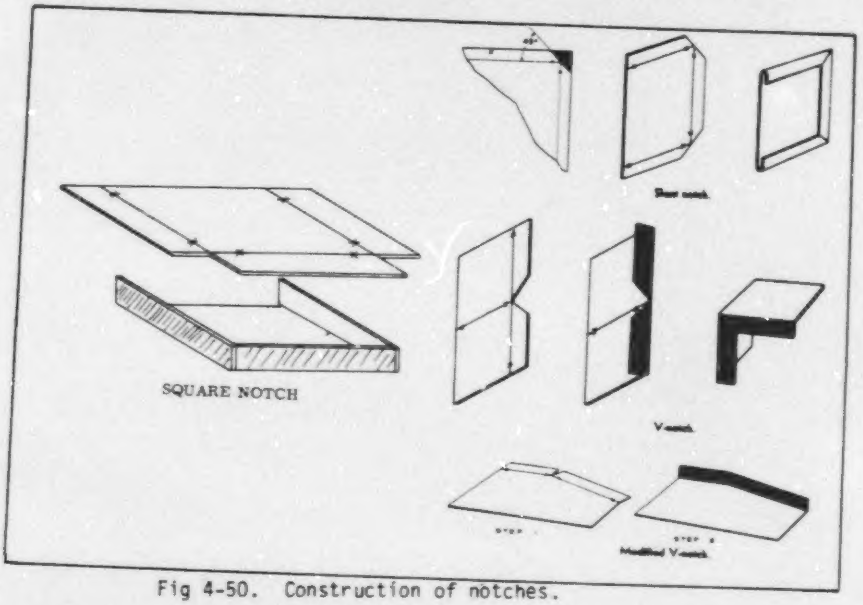

45°
Slant notch
SQUARE NOTCH
V-notch
STEP 1
STEP 2
Modified V-notch

Fig 4-50. Construction of notches.

A wire notch is used with a wired edge. Its depth from the edge of the pattern will be one wire's diameter more than the allowance for the wire edge (2 1/2 d) or, in other words, it will be 3 1/2 times the diameter of the wire. The shape of the notch on the seam will depend on the type of seam used, which in figure 4-51 is 45° for a grooved seam.

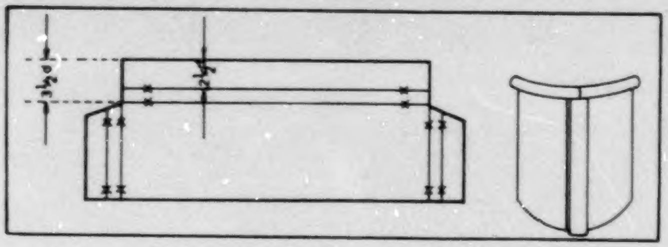


Fig 4-51. Wire notch in cylindrical layout.

c. Joining the seams. Not all, but a large majority of the seams in sheet-metal work will be riveted. Rivets are available in a variety of sizes and heads. The tinner's rivet shown in figure 4-52 is the type that you will most likely come in contact with. It will vary in size from the 8-oz to the 12-lb rivet. This designation is the weight of 1,000 rivets (1,000 of the smallest size weigh 8 oz). As the weight per 1,000 rivets increase, the diameter and length of the rivets increase. The 8-oz rivet has a diameter of 0.089 in. and is 5/32 in. long, while the 12-lb rivet has a diameter of 0.259 in. and is 1/2-in. long. For special jobs that require fastening several thicknesses of metal together you will use a rivet that has an extra long shank, but the same diameter as the rivet you would normally use. Select the proper rivet size for the gage of metal you intend to fasten. Figure 4-53 will be of help in selecting the proper rivet. You will determine rivet spacing from the drawing or blueprint. If the spacing is not indicated, the type of seam will indicate the spacing of the rivets. A job that has to be watertight will have more rivets per inch than a job that does not. Whether the spacing is close together or far apart, be sure that you allow a distance of 2 times the diameter of the rivet from the edge of the sheet when locating the centerline for the rivet hole. When you have determined the rivet size and the location of the rivet hole, your next step will be to make a hole. You can either drill the hole or punch the hole. If the location of the hole is near the edge, the hand punch illustrated in figure 4-54 will serve to good advantage. Rivets are not always located near the edge of the sheet, and you may have to drill. Whether you punch or drill the hole, remember that the hole must be slightly larger than the rivet you have selected. You will use a rivet set to draw the two pieces of metal together and head the rivet. Select two pieces of scrap metal and determine the correct rivet size from figure 4-53. Lay out and punch the holes.

Fig 4-52. Tinner's rivets.

Gage of metal	Size of rivet (pounds)
26-----------	1
24-----------	2
22-----------	2 1/2
20-----------	3
18-----------	3 1/2
16-----------	4

Fig 4-53. Guide for selecting rivets.

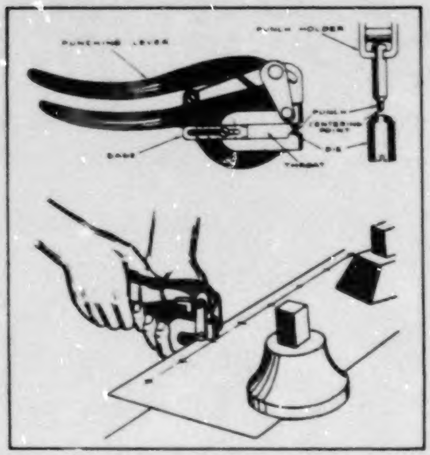

PUNCHING LEVER
PUNCH HOLDER
PUNCH
CENTERING POINT
DIE
GAGE
THROAT

Fig 4-54. The hand punch.

(1) Select the rivet set having a hole slightly larger than the rivet diameter.

(2) Insert the rivets in the holes and rest the sheets to be joined on a stake or solid bench top with the rivet heads against the bench top.

(3) Draw the sheets together by placing the deep hole in the rivet set over the rivet shank and striking the head of the rivet set with a riveting hammer. use a lightweight hammer for small rivets and a heavier hammer for heavier rivets.

(4) When the sheets are properly drawn together, remove the set and strike the end of the rivet a blow from the riveting hammer to upset the rivet. Don't strike too hard a blow, as it will distort the metal around the hole.

(5) Place the dished portion of the rivet set (the heading die) over the rivet and form the head. One or two blows are sufficient to form the head. A correctly drawn, upset, and headed rivet is illustrated in figure 4-55. Avoid the troubles in the lower half of the illustration.

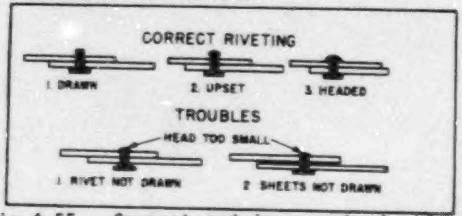

CORRECT RIVETING
1 DRAWN
2 UPSET
3 HEADED
TROUBLES
HEAD TOO SMALL
1 RIVET NOT DRAWN
2 SHEETS NOT DRAWN

Fig 4-55. Correct and incorrect riveting.

Remember that it is not necessary to strike the rivet set with all the power you can muster to do a good riveting job. Use just enough force on the hammer to do a good sheet-metal riveting job. When it is necessary to rivet a seam on a cylindrical object (fig 4-56), you can use the hallow mandrel stake or other suitable bars to buck the rivets. On the seams, insert rivets in the end holes, slip the piece over the stake, and draw the seam together. Strike the rivets hard enough to upset the rivets enough to hold the seam together. Insert the center rivet, draw, upset, and head this rivet. Complete the seam by riveting from the center out to one end and then to the other end. Complete the job by drawing and heading each rivet.

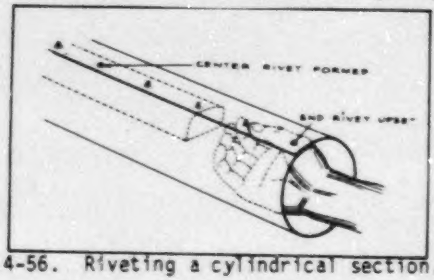

CENTER RIVET FORMED
END RIVET UPSET

Fig 4-56. Riveting a cylindrical section.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The longest stretchout dimension (seams not included) of a cylindrical pipe 1 1/2 ft. long and 6 in. in diameter will be _________ inches.

   a. 4.71 c. 18.0
   b. 6.0 d. 18.8496

2. The method used to develop a pattern of an intersected pipe is

   a. parallel line. c. radial line.
   b. angular. d. geometric.

3. The method used to develop a pattern of a cone is

   a. parallel line. c. radial line.
   b. angular. d. geometric.

4. You are making a wired edge on an ice cube tray with wire 1/16 in. in diameter. You must allow _________ in. for the wired edge.

   a. 1/32 c. 5/32
   b. 1/16 d. 5/16

5. The allowance for a lap seam which is to be riveted with 1/8 in. rivets is _________ inch.

   a. 1/8 c. 1/2
   b. 1/4 d. 3/4

6. In making a corner lap seam which is to riveted, your allowance for clearance should be

   a. 4 times the diameter plus 1/16 inch.
   b. 2 1/2 times rivet diameter.
   c. 4 times rivet diameter.
   d. 1/2 the lap width.

7. If a 3/8 in. grooved seam is specified, your allowance on each edge would be _________ inch.

   a. 3/8 c. 3/4
   b. 9/16 d. 1 1/8

8. The type of seam used for the construction of a cylinder is a _________ seam.

   a. grooved c. plain lap
   b. Pittsburgh lock d. off set lap

9. With reference to the pocket depth on the Pittsburgh lock seam, the width of the flanged edge must be

   a. more. c. the same.
   b. less. d. twice the pocket depth.

10. Rivets for a lap seam are set _________ rivet diameter from the edge.

    a. 1 1/2 c. 2 1/2
    b. 2 d. 3

11. When the single-hem edge is to meet at a 90° angle, the type of notch used is the

    a. slant. c. wire.
    b. modified "V". d. square.

12. If the inside flange is to be constructed on an angle of less than 90° a _______ type notch would be used.

    a. slant c. "V"
    b. square d. modified "V"

13. The depth of the wire notch from the edge of the pattern will be

a. 1 1/2 times the width of the seam.
b. 2 times the width of the seam.
c. 2 1/2 times the diameter of the wire.
d. 3 1/2 times the diameter of the wire.

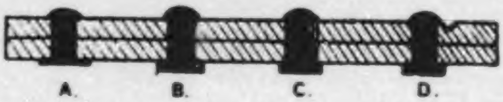
14. The shape of a wire notch will depend on the

a. type of wire.
b. size of wire.
c. type of seam.
d. size of seam.

15. The tinner's rivet size is designated by the

a. weight of 1,000 rivets.
b. weight of 100 rivets.
c. diameter of rivet shank.
d. length of the rivet shank.

16. In the illustration, the figure which shows the correctly drawn and headed rivet is __________.



SUMMARY REVIEW

In this study unit, you learned to identify the use of Metalworking Machines and Special Tools utilized within the Marine Corps.

Answers to Study Unit #4 Exercises

Work Unit 4-1.

1. d.
2. c.
3. b.
4. c.
5. a.
6. c.

Work Unit 4-2.

1. d.
2. a.
3. b.
4. c.
5. c.
6. a. snips
   b. riveting tools
   c. striking tools
   d. layout tools.

Work Unit 4-3.

1. d.
2. a.
3. b.
4. c.
5. d.
6. a.
7. c.
8. c.
9. a.
10. b.
11. d.
12. c.
13. c.
14. b.
15. b.
16. a. slip-roll forming
    b. Rotary
    c. Cornice
    d. Box and pan brake
    e. Bar folder
    f. Deep-throat bending
    g. crimping
    h. Setting down

Work Unit 4-4.

1. d.
2. a.
3. c.
4. c.
5. c.
6. a.
7. b.
8. a.
9. b.
10. b.
11. a.
12. d.
13. d.
14. c.
15. a.
16. b.

STUDY UNIT 5

EQUIPMENT REPAIR

STUDY UNIT OBJECTIVES: UPON SUCCESSFUL COMPLETION OF THIS STUDY UNIT YOU WILL IDENTIFY THE TOOLS AND PROCEDURES FOR REPAIRING FRAMES AND BODY METALS.

General

All of the materials used in the manufacture of engineer/ordnance equipment, as well as the assembled equipment, are thoroughly tested before being issued for field use. Therefore, most of the damage and failures of this equipment will be due to accidents, overloading, or unusual shocks which the equipment was not designed to withstand. It is the class of repair work that you, the metalworker and welder, will be doing most frequently. Before repairing any damaged equipment, it must be determined whether or not the materials can be satisfactorily welded or must be repaired in some other way. This can be decided by giving consideration to the determinations listed below:

Determine the nature and extent of the damage and the amount of straightening and fitting of the metal that will be required.

Determine the possibility of restoring the part to usable condition without the use of heat.

Determine the type of metal used in the damage part and, if it was heat-treated, what method was used to do so.

Determine if the welding heat will distort the shape or in any manner impair the physical properties of the part to be repaired.

Determine what method and materials will be required to make the repair.

Work Unit 5-1. METALWORKING TOOLS.

LIST THE FOUR HANDTOOLS USED IN EQUIPMENT REPAIRS.

For repairing sheet-metal sections, you can generally get by with the minimum number of tools. Some of these tools were discussed in Study Unit 4. They consisted of stakes, punches, shears, and hammers. The ones that we are mainly interested in here are those that are used to restore automotive sheet metal such as doors, hoods, fenders, etc., to their orginal shapes. These tools are the dolly blocks, hammers, body files, and disk grinders.

a. Hammers (fig 5-1). The hammer that you will be using are by far the most important tools for restoring sheet metal to its original shape. There are many different types and each is designed for a particular operation.

(1) Pick hammer (fig 5-1A). The pick hammer is tapered to a point on one end and has a curve to the pick so that, when it is used with the proper wrist action, the point of the pick will strike the point at which you aim. It is used to raise surfaces which are badly dented. In most instances, this hammer will be used from the underside of the damaged area.

(2) Bumping hammer (fig 5-1B). This hammer is the one that you will probably use most. There are different variations of this hammer; some have short shanks (fig 5-1C) and some have the round head serrated (not illustrated). You will notice that one end of the hammer has a square head and the other a round head. The short shank version shank version is used where working space is restricted. The serrated version is used where roughing out of badly dented sections is necessary. These hammers are used mostly for roughing out damaged sheet metal.

(3) Short pick hammer (fig 5-1D). This is nothing more than a smaller variation of the long shank pick hammer and is of course used where space is restricted. There are other more sophisticated body hammers, but with these four and a rubber and wooden mallet you should be able to accomplish most of the work necessary to repair a damaged section of sheet metal.

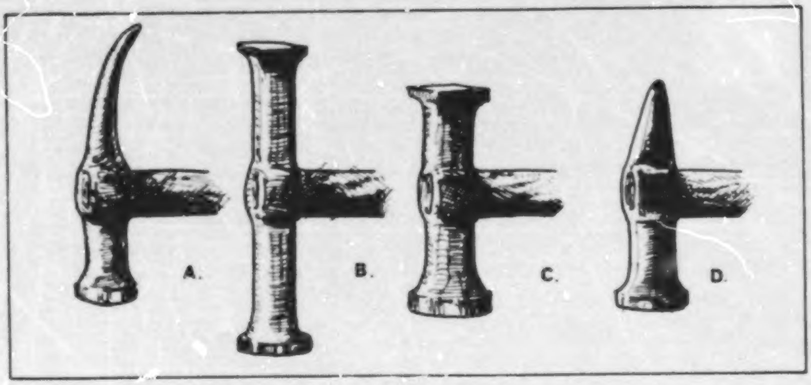


Fig 5-1. Body hammers.

b. Metal dollies (fig 5-2). Dolly blocks are used in conjunction with bumping body hammers to straighted out damaged sheet metal. Dolly blocks or hand anvils are available in several types: Heel, low crown, toe, general-purpose, heavy-duty, and utility. Each type is used for supporting damaged sheet metal during straightening operations.

(1) Low crown. The low crown dolly is used in areas such as door or hood panels where a medium or high crown dolly would stretch the metal.

(2) Toe dolly. The toe dolly (shrinking dolly) is used on flat panels. Its thinness and length give it access to narrow pockets. The large flat face is convenient when shrinking metal. The flat sides are used as an anvil for repairing flanges on metal.

(3) General-purpose. This is a convenient dolly to hold and has several different working faces and two beading and flanging lips. It is the most useful of the dollies since it has unlimited applications.

(4) Utility. This dolly has a high crown with one narrow beading edge. The thick rounded sides are used in short-radius curves. The high crown is used where there is a high crown area such as a fender.

(5) Heavy-duty. This is used where the extra heavier gage of metal resists the action of the lighter dollies.

(6) Heel dolly. The heel dolly is used to reach into sharp corners and into an area having a large radius.

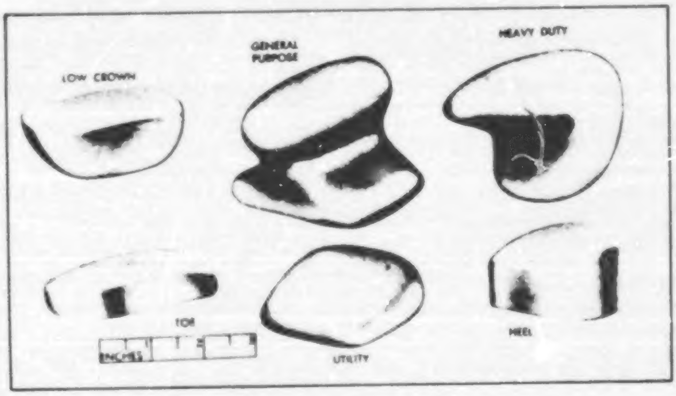


Fig 5-2. Metal dollies.

c. Body file (fig 5-3). A body file is used to smooth out the metal after the hammering operation is finished. It is also used to cut lead and body fillers. Using light strokes on the file will show up the high and low spots on sheet metal so that additional raising or shrinking can be done. The body file consists of a file holder that works on the same principle as the hacksaw frame and a metal file blade which has rows of single-cut, curved, milled parallel edges. When coupled to the file holder, the blade can be made to assume the shape and contour of the sheet metal being worked on by use of the adjusting screw. As the teeth of the file blade are parallel and are sharpened so that they can cut in one direction only, repeated dragging back on the file while under pressure only serves to dull the cutting edges of the teeth. Using light forward strokes and raising the file from contact with the sheet metal at the end of each stroke will keep the teeth sharp and extend the life of the file blade.

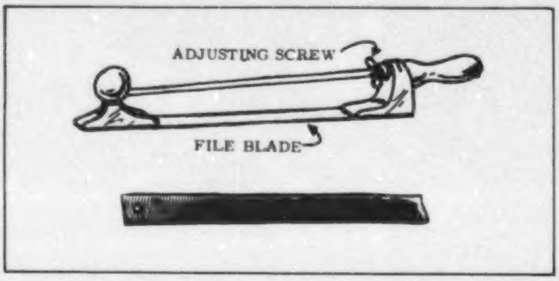


Fig 5-3. Body file and blade.

d. Sanding machine and abrasive disks.

(1) Disk sander. The disk sander normally used for sheet-metal work is the electric portable, 115-volt, heavy-duty disk sander which is a component of the shop equipment repair set. It has a right-angle drive arbor and a 7-in. diameter abrasive disk. It is used to remove paint and rust, to grind out high spots, and to restore the original shape of the sheet metal after it has been either welded or filled with body lead or body fillers. When using the sander you should always wear goggles to protect your eyes from flying particles of metal, abrasives, and dust that are always present.

(2) Abrasive disks. Sanding disks come in two classes, the open coat and the closed coat. The difference is the manner in which the abrasive particles are applied to the backing material. In the open coat disk, the abrasive is applied so that there are spaces between the particles and the backing material that are not completely covered, whereas on the closed coat the backing material is so saturated with the abrasive material that there are no spaces between particles. The backing material used is either paper, cloth, or a combination of both. The abrasive material is usually flint, garnet, aluminum oxide, emery, or silicon carbide. The material used to hold the abrasive to the backing paper depends on the purpose for which it is to be used. If the sandpaper is to be used with water or for wet sanding, the abrasive is glued to the backing material with a resin glue. For dry sanding purposes, an animal glue is used. The particles are designed by grit size such as 400, 300, 200, or 210, 310. The higher the number, the finer the grit; the lower the number, the coarser the grit.

EXERCISE: Answer the following questions and compare your responses with those listed at the end of this study unit.

1. Before making a welding repair to any equipment, you should

a. heat-treat the part.
b. anneal the weld area.
c. identify the type of material.
d. normalize the metal.

2. To raise the surface of a badly dented door panel, you would use a

a. rubber mallet.
b. pick hammer.
c. bumping body hammer.
d. low crown dolly.

3. The dolly which has unlimited applications is the

a. utility.	c. heel.
b. low crown.	d. general purpose.

4. List the four types of hand tools used in repairing body damage.

a.	c.
b.	d.

AUTOMOTIVE EQUIPMENT

a. Welding automotive equipment.

(1) General. Marine Corps automotive equipment, such as tanks, trucks, tractors, and other vehicles, is constructed from a large number of metals that are processed under various heat-treatments. The metals used include copper alloys, carbon and alloy steels, titanium, aluminum, magnesium, lead, etc. The principle joining processes that may be used are gas and electric-arc welding, brazing, and soldering. The use of welding equipment and the application of welding process to different metals have been covered previously and a thorough working knowledge of these processes is a necessity before a welding procedure for any given job can be selected. When it has been decided by competent personnel that the repair can be made by welding, the factors listed below should be considered:

The proper size and type of electrode, together with the current settings and polarity, must be determined if an arc-welding process is used. If a gas-welding process is used, the proper type of welding rod, the correct gas pressure, tip size, flux, and flame adjustment must be determined.

In preparing edges of plates or parts to be welded, the proper cleaning of the parts to be joined should be considered. The need for backup strips, quench plates, tack welding, and preheating must be determined.

Reducing warping and internal stresses requires the use of proper sequence for welding, control and proper distribution of the welding heat, spacing of the parts to permit some movement, control of the size and location of the deposited weld metal beads, and proper cooling procedures.

(2) Welding cast iron, cast steel, carbon steel, and forgings. In general, parts composed of these metals can be repaired by the same procedure as that used for their assembly, or by brazing. For instance, cast iron and cast steel may be repaired by gas welding, arc welding, or by brazing. Parts or sections made of carbon steel originally assembled in the factory by spot, projection, or flash welding, may be repaired by gas or arc welding or by brazing. This is also true of forgings.

(3) Heat-treated parts. Certain parts of automotive equipment are heat-treated during their manufacture to enable them to withstand the service for which they are intended. Welding of these parts should not be attempted unless the repair shop is equipped with suitable heat-treating equipment. In some cases, alloy steels or specially heat-treated parts may be repaired by using stainless steel filler metal. When this is done, a heat-affected zone that is weaker than the original heat-treated part will remain in the vicinity of the welded joint. Where it is possible to heat-treat parts after welding, they should be first annealed. Filler metal of the same composition of properties as the base metal should be used and the parts should be heat-treated after welding.

(4) Welding truck components.

(a) Frames. The truck member most frequently repaired by welding is the frame. Truck frames are usually made of heat-treated alloy steel and are subjected to high bending, torsion or twisting, and impact loads. A commonly used method for repairing and strengthening a broken or weakened frame is with reinforcing plates as shown in figure 5-4. The type of reinforcement selected depends on the location of the repair and possible interference with other elements of the truck. It should be noted that the ends of the reinforcing plates are not welded, because welds across the ends of the plates will produce heat-affected areas of decreased strength across the back and legs of the channel. All interfering welds and other protrusions should be ground flush before reinforcing plates are applied. These reinforcing plates should be approximately the same thickness as the frame element and the width should be sufficient to bring the weld flush with the top and bottom sections of the channel. The procedure outlined for reinforcing channels should be followed when reinforcing plates are added to angles, trees, box sections, or I-beams. The arc-welding method is used to weld truck frames.

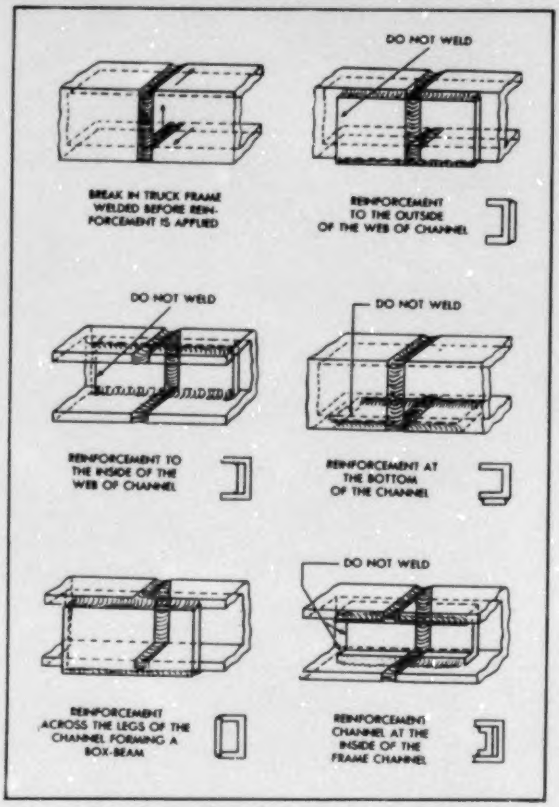

DO NOT WELD
BREAK IN TRUCK FRAME WELDED BEFORE REINFORCEMENT IS APPLIED
REINFORCEMENT TO THE OUTSIDE OF THE WEB OF CHANNEL
DO NOT WELD
DO NOT WELD
REINFORCEMENT TO THE INSIDE OF THE WEB OF CHANNEL
REINFORCEMENT AT THE BOTTOM OF THE CHANNEL
DO NOT WELD
REINFORCEMENT ACROSS THE LEGS OF THE CHANNEL FORMING A BOX-BEAM
REINFORCEMENT CHANNEL AT THE INSIDE OF THE FRAME CHANNEL

Fig 5-4. Reinforcing truck frames.

(1) Front axles. The front axles of standard automotive equipment are made of heat-treated alloy drop forgings. Repairs by welding should not be make on these axles except in an extreme emergency and then only as a temporary measure.

(c) Rear axle housings. These are of welded pressed steel construction of great strength and simplicity of design. The pressed steel and cast-steel housing can be satisfactorily welded by the arc method. Some of the older types of axle housings are made from malleable iron; housings of this type can be repaired by brazing. Castings should be kept clean and cool to prevent any effect on the heat-treatment or annealing in the vicinity of the weld.

(d) Drive shafts. Drive shafts are usually made out of medium carbon seamless tubing and are readily welded by either the electric-arc or gas-welding method.

(e) Radiators. Radiators can be repaired with an oxyacetylene torch with a proper tip, common 50-50 solder, and a flux. The flame should be adjusted to give a highly carburizing mixture. The areas around the leaks in the copper tubes should be thoroughly cleaned, preferably with a 5% solution of hydrochloric acid, and tinned before the joint is made in order to assure a tight joint. Where a leak is present at joints between copper and cast iron, the surface should be pickled before the repair is made. This is done by applying a 5% hydrochloric acid solution to the iron at the joint and heating until the iron is thoroughly cleaned. This treatment removes surface oxides, scale, and other impurities and makes the iron capable of being tinned as readily as the copper.

b. *Tractor repairs*. Except for the frames and suspensions, the construction of the tractors is about the same as for commercial trucks. The metal used for crankcase housings, transmission, differentials, main frames, and track frames can be repaired by the electric-arc or the gas-welding method. The rollers and idlers can be built up with hard-surface alloys to extend their life usage. The cutting edges on the blades can also be hard-surfaced to prolong the life of cutting edges.

c. *Welding artillery equipment*. When welding artillery equipment, the low- and medium-carbon steels can be satisfactorily welded with mild steel electrodes or welding rods and, where it is necessary, severely damaged sections can be strengthened with suitable reinforcing plates. Trails that have been bent out of shape and cracked should first be straightened by the careful application of heat. The cracks should be welded and ground flush before reinforcing plates are applied. The reinforcing plates should be thick enough to provide the necessary strength without making the structure too stiff. Only the seams running along the length of the trail should be welded on all reinforcing plates; the ends of the plates are left unwelded. Welding the ends would simply transfer to the welded ends of the reinforcing plates the conditions existing in the welded joint before the reinforcing was added. This would result in weakness at this section and would defeat the purpose of the reinforcing plate. Trails constructed of structural nickel alloy steels are designed for lightness and are specially treated for maximum strength. Welding steels of this nature presents a more difficult problem. The top carriages or cradles should not be welded. Other structural members can be welded when approved by the proper authorities. Field repairs can be made by proper preheating; welding with a nickel alloy, 25-20 stainless steels, or modified 18-8 stainless-steel electrodes; and finally, by slow cooling and uniform stress-relieving heat-treatment where possible. For many applications, welds can be made with these stainless-steel electrodes without preheating.

d. *Tank repairs*. Armor plate is used for the protection of personnel and equipment in tanks, self-propelled guns, and other combat vehicles. Industrial manufacture of gun turrets and combat tank hulls includes designs using 1-piece castings and welded assemblies of cast sections and rolled plates which are selectively heat-treated to develop desired properties. In certain cases, cast sections using the 1-piece design are bolted in place to facilitate the requirements of maintenance through unit replacement. Armor plate is an air-hardened alloy steel, which means that it will harden by normalizing or heating to its upper critical point and cooling in still air. The extremely high temperatures that occur in the area of the welded joint will cause a narrow zone on each side of the weld deposit to form a hard and brittle zone. It is in this zone that cracks are more likely to appear as a result of the sudden application of loads. For this reason, special precautions must be taken in the welding operations to minimize the formation of these hard zones and to limit their effect on the structural properties of the welded armor. In order to prevent the formation of cracks in these hard zones, care must be taken to prevent rapid cooling after welding. The two types of armor plate used in combat vehicles are face-hardened (rolled) and homogeneous (cast or rolled). It is necessary, before any welding operations are performed, that the armor be specifically identified, as there are different welding procedures for the two different types of metals. Homogeneous armor is heat-treated throughout its entire thickness to develop good shock or impact resistance. It is uniform in hardness, composition, and structure and can be welded from either side. Face-hardened armor plate, as its name implies, has an extremely hard surface layer obtained by carburizing, which extends to a depth of 1/5 to 1/4 of the outward facing thickness of the plate. The primary purpose of this is to provide good resistance to penetration. The inner side is comparatively soft and has properties similar to those of homogeneous steel. Face-hardened steel up to thicknesses of 1/2 in. should be welded from the soft side only. The test for identifying the type of armor is simple but accurate. A file will bite into both sides of the homogeneous steel, whereas it will bite only into the soft side of the face-hardened steel. When applied to the hardened side, the file will slip and not bite into the metal. The most satisfactory method for repair of homogeneous and face-hardened steel is electric-arc welding with stainless-steel electrodes. The oxyacetylene process requires heating of a large section of the base metal on either side of the prepared joint in order to maintain a welding puddle of sufficient size at the joint. This heating destroys the heat-treatment imparted to the armor plate thus causing large areas to become structurally weak. In addition, this procedure is slow and produces considerable warpage in the welded sections. Electrodes containing 18% chromium and 8% nickel in the core wire and small percentages of either manganese or molybdenum, or both, added in the electrode coating, produce good results. These electrodes are recommended for welding all types of armor plate by the electric-arc process without preheating or postheating the structure to be welded. They should be all-welding position type. These electrodes are known as manganese modified 18-8 stainless-steel electrodes. The recommended welding current settings shown below are for the direct-current, reverse-polarity, all-position, heavy-coated modified 18-8 stainless-steel electrodes. The exact current settings will be governed by the joint design and position of welding.

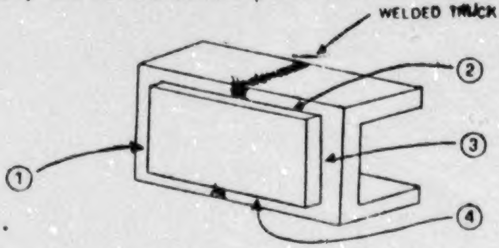
Electrode diam (in.)	Current range (amps)
1/8	90 to 100
5/32	110 to 130
3/16	150 to 180

EXERCISE: Answer the following questions and compare your responses against those listed at the end of this study unit.

1. The repairs that can be made in the field without heat-treating by oxyacetylene is

   a. cracked transmission housing.
   b. broken diesel engine connecting rod.
   c. broken truck transmission gear.
   d. broken leaf spring.

2. In the diagram below, the reinforcement plate should be welded at



   a. 1 and 2.
   b. 2 and 4.
   c. 3 and 4.
   d. 1, 2, 3, and 4.

3. The method you should use to repair a radiator core is

   a. soldering.
   b. brazing.
   c. fusion welding.
   d. arc-welding.

4. The method, if any, to weld the cradle of an artillery piece is

   a. soldering.
   b. electric arc.
   c. brazing.
   d. none recommended.

5. The primary purpose of face-hardened armor is to

   a. resist corrosion.
   b. provide stronger construction.
   c. make welding easier.
   d. provide resistance to penetration.

Work Unit 5-3. REPAIRING BODY DAMAGE

LIST THE FOUR PROCEDURES FOR REPAIRING BODY DAMAGE.

Body repairs include straightening of body panels, replacing body parts, and repainting. Since the Marine Corps areas of operations are usually located where severe climate conditions exist, such as near salt water or in sandy, hot areas, vehicles are subject to intense deterioration. For example, salt water will rapidly rust body panels. Much of our equipment sooner or later will find its way aboard ships for overseas deployment and, as a result of this, salt-water corrosion and shipping damages are also prevalent. Another great cause of body damage is, of course, accidents. All that is required to repair a damaged part is the necessary tools and the required skills. In cases where severe body damage exists, it may be more economical and expedient to replace the part rather than repair it. To help you decide when this is the case, some of the following questions should be answered:

Urgency of the job. Will it take longer to repair a badly damaged section than it will to replace it?

What is the availability of repair parts?

What is the availability of the men and equipment to do the repair job?

The speed and ease with which repairs are made to damaged areas depends on starting the job correctly. When a collision occurs, there will always be a major depression in the panel followed by a buckled area and then by a series of ridges. The correct procedure to repair this damage is to reverse the order in which the damage occurred. To help you understand this procedure, refer to figure 5-5 and the following discussion. Assume that the original form of the panel in the illustration is the solid line designated 1. The depression formed as a result of a collision is the broken line 2. This is where the panel was struck, and the ridge formed 3. To return this panel to its original shape and contour, the work, or course, must be reversed. That is, the ridge (3) must be where the work starts. By hammering at the area indicated by 4, this ridge will be forced down and you will find as it is removed, the major depression (2) will also spring back close to its original contour. The remaining dents can be removed with a dolly block and hammer. Select a dolly block with the same general shape or curvature as the panel. Hold the block under the panel and strike the high points of the dents with the hammer. Always use light hammer blows, as heavier blows tend to stretch the metal. Continue to do this until the dents appear to be gone. Use a body file across the surface and take light cuts. These will show you the high and low spots. The spots that take the heaviest cuts still need more dolly and hammer work. The light high spots that cannot be removed with dolly and hammer can usually be removed with the disk sander.

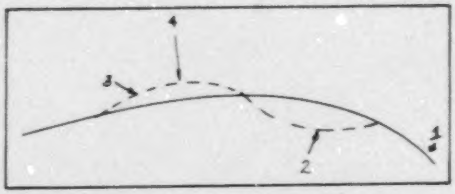


Fig 5-5. Removing dent from damaged panel.

a. Bumping and dinging. Bumping is the restoration of damaged areas without regard to the finished painted surfaces. Dinging, on the other hand, is removal of dents without damaging the finish so as not to have to refinish the surface. Dinging is a highly skilled craft requiring years of experience to remove a dent without marring the finish of a panel. For our purpose rarely will there be a case where a dent will have to be removed without repainting the damaged area, so the terms as used here will be synonymous. To use the dolly blocks with a bumping hammer, the block is held against one side of the panel (usually the underside) with one hand. The other hand is used to strike the opposite side with the hammer. As the blow is struck, the dolly rebounds slightly from the panel, but returns immediately because of the pressure exerted by your hand. As the dolly returns, it is placed in position for the next blow of the hammer.

(1) Dinging on the dolly (fig 5-6). Dinging on the dolly means a glancing or slapping blow of the body hammer on top of sheet metal, with the dolly block held directly below the hammer blow. The result of this process is that the metal is ironed smooth between the working faces of the block and hammer. Each blow dings an area or spot about 3/8 in. in diameter. Succeeding blows should be struck so that one spot overlaps the previous spot. Ding a row of spots across the damaged area, next ding another row adjacent to the first row, and so on, until the damaged area is covered with parallel rows of spots. This stretches the metal very slightly. The low crown hammer face striking against the dolly, which closely fits the contours of the panel, minimizes the stretching.

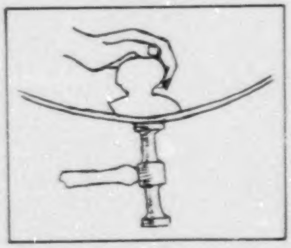


Fig 5-6. Dinging on the dolly.

(2) Dinging off the dolly. The high crown face of the body hammer is used and the blows are directed against the rim of the dent. The dolly block is held against the bottom of the dent and pressure is exerted to force the dent out as illustrated in figure 5-7.

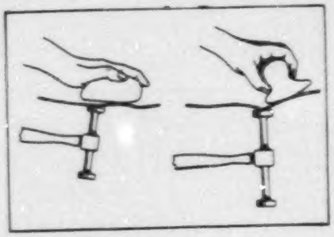


Fig 5-7. Dinging off the dolly.

(3) Using the body hammer (fig 5-8). The hammer blow used in dinging is not a follow through blow such as used when driving nails. The hammer must be held loosely and swung with a wrist action, producing a slapping blow. Figure 5-8 shows the path through which the hammer travels. The average number of blows per minute is 120 in a regular rhythm. As each succeeding blow is struck, the hammer rebounds as shown. It is then lifted by wrist action to a point high enough to start the next blow. Then, by a snap of the wrist, the hammer descends for the next blow. At no time is the hammer gripped firmly. The fingers are used to guide and control the hammer at the beginning and at the end of the blow. During the downward and upward path of the hammer head, the end of the handle moves through a short arc and the hand by continued wrist action follows along loosely holding the handle and ready to grasp it more firmly at the end of the rebound. This operation requires skill, but can be acquired with a little practice.

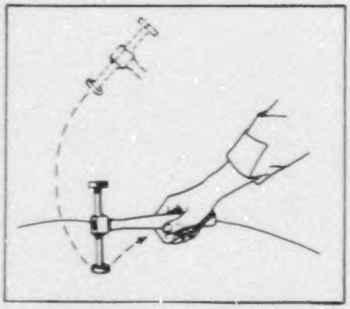


Fig 5-8. Using a bumping body hammer.

b. Shrinking sheet metal (fig 5-9). When a panel has been damaged so that it is permanently stretched, it will, after it is restored to shape, be too high in the stretched area. It cannot be dinged down since there is no place for the metal to go. It must be shrunk. Shrinking should always be done following the metal bumping and before the metal is finished. Basically, the shrinking operation is simply done by heating a small spot in the center of the stretched area and then upsetting the stretched metal into this heated spot, making it thicker. Shrink a stretched area in sheet metal by using a suitable torch with a small tip. Heat a spot 3/8 in. in diameter to a little past cherry red in the center of the stretched area (fig 5-9). The heat expands the metal in the entire stretched area, while the spot itself rises into a low peak. Use care to avoid burning a hole in the metal. After the spot turns cherry red, remove the torch and strike the spot with a hard blow from the bumping body hammer to drive the spot down. The hammer blow upsets the hot metal and is the mechanical action which shrinks the metal. The spot will now form a crater instead of a peak. Very quickly, hold a dolly block up against the bottom of the crater. At the same time, tap down the rim of the crater with the body hammer. This is simply a "dinging off the dolly" operation to smooth the spot to the proper level before metal finishing. The expansion in the metal during this operation. When dinging the upset metal smooth, use a low crown dolly block under low crown metal, and a high crown dolly block under high crown metal. Finally, with a wet, water-soaked sponge, chill or quench the area about 6 inches in diameter around the spot. This chilling draws the expansion out of the metal very quickly. Continue to shrink additional spots until the contour of the panel is in proper shape, as determined by feeling with the hand or examining by sight.

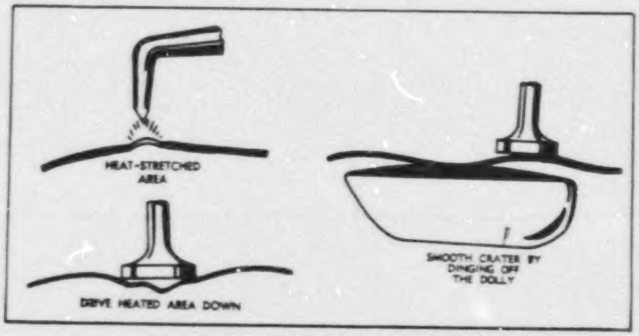


Fig 5-9. Shrinking sheet metal.

c. Applying body fillers. When body panels have rusted through or have been dented in such a manner that it is extremely difficult to remove these dents, the damage can be repaired by cutting out the damaged area (in the case of rust) and welding in a new section of sheet metal, or by using one of the many commercial methods that have been developed over the years. The two methods we will discuss are the lead solder method, which is probably the oldest method used to repair damaged bodies, and the plastic body filler. The solder method is very effective when properly used and applied. The plastic body filler, the newest method and the one used most by bodymen today, is the easier of the two to apply even by the inexperienced man, and does a very satisfactory job provided that the manufacturer's instructions are followed. Whichever method is used, the surface of the sheet metal must first be prepared and cleaned of all foreign materials and the paint must be removed down to the metal surface itself.

(1) Lead. This is the most difficult to apply and takes considerable skill. Lead solder is used extensively for filling small dents and smoothing rough surfaces which are difficult to straighten. The only prerequisite for soldering is to be certain that the damaged area is thoroughly cleaned so that the tinning of the surface can be accomplished. Tinning is necessary to prepare the surface so that when the solder is applied it will stay.

1st step: Cleaning. To remove all paints and surface oxides from the damaged area, use an open-coat 16B aluminum oxide sanding disk. Sand the area until the metal is clean and shining.

2nd step: Preheating. After you have prepared the surface to receive the solder, use an oxyacetylene torch to preheat the surface by playing it back and forth over the damaged area. Use an acid-core solder (this is easier as the flux is contained in the center of the solder) and heat the surface until the solder melts when it comes in contact with the surface. Apply the solder to the surface with a rag and smear it over the surface of the damaged area.

Note concerning building up of damaged area (the 3rd step). Now you are ready for the third step, which is to apply solder and build up the damaged area slightly higher than the original contour of the panel. To fill this area, you can continue to use the roll solder or bar solder. The roll solder comes in different sizes and is obtained by the pound. The bar or "stick" solder is obtained by the stick and is identified by numbers which indicate the amount of tin and lead; for example, 30/70 indicates solder containing 30% tin and 70% lead. The first number is always the percentage of tin.

3rd step, if using bar solder. When using bar solder to fill in the area of damage, after you have properly tinned the surface, you keep the surface hot by playing the torch over it. Heat the bar of solder with the torch until about 3/4 to 1 inch of it starts to melt and droop, then press this on the damaged area. Build the surface up in this manner until you obtain the desired height. You will want the solder to be slightly higher than the original contour of the sheet metal on which you are working.

3rd step, if using roll solder. When building up with the roll solder, you keep the sheet metal just hot enough to keep the tinning coat soft, but not hot enough that the tinning coat will melt and run. Apply the torch to the solder until it begins to melt and droop, then quickly press it on the metal surface. Build the surface in this manner until the desired height is reached.

4th step: Paddling. When you have applied enough solder, using either the bar or roll method of step 3, go to the next step and smooth out the solder and establish a contour conforming to that which you are working on. This is done by "paddling." The surface, which is now covered with solder, is kept at a temperature that is just below the working stage of the solder by using the torch. The area which you are now going to work on is heated to bring the solder up to a workable stage and, with a solder paddle, you smooth the solder and shape it to the desired contour. You keep the torch on the spot that you are working on only long enough to heat the solder to a working stage, then remove it. If the solder is allowed to melt and run, the whole rebuilding operation will have to be started over. The paddle surface should be kept lightly coated with oil to prevent the solder from sticking to it.

5th step: Allow to cool. After you have smoothed the area and obtained the contour, you allow the solder to cool.

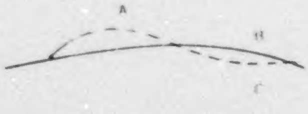
6th step: Finish with a body file. After the solder is cold, the next step is to finish the solder area with a body file. Do not use a disk sander for this operation. Finish the area by working the outside edges first and then working the center until the correct contour is obtained.

(2) Plastic body putties. One of the newest and easiest methods of patching and filling dents is using plastic body putties. These are puttylike substances that when mixed with a catalyst, which is furnished with the putty, set up a chemical action and convert the putty into a hard, plastic finish which can be filed, sanded, and even drilled. When sanding with a disk sander, you should wear a respirator as the fine particles that emanate from the plastic are harmful to the lungs. Since it takes only a few minutes for the putty to dry, you should mix only that amount which can be used before it hardens. Most putties show a color change when mixed with the hardener and this change will show you whether or not the putty is mixed thoroughly. Mixing is best done on a smooth surface, such as a sheet of glass or a piece of metal. After the putty is mixed, it is applied with a putty knife or a piece of hard rubber using a "squeegee" action, by wiping the putty over the area to be repaired. If the dent to be filled is deep, the putty should be applied in thin layers to allow each layer to dry sufficiently. If holes are encountered in the metal, they can be filled by backing up the putty with a piece of ordinary screen wire. This allows the putty to penetrate the holes in the screen wire and serves as a base for adhesion. The build-up area should be filled slightly higher than the original contour to allow for filing and sanding. If, after filing and sanding, small pits are still present, a "glazing putty" can be used to fill these small pits (this is also done when filling with solder). It is wiped on with a putty knife or rubber squeegee. To allow for sanding, this should also be applied to a slightly higher than original contour.

d. Finished-surface preparation. After all body work is completed and all rebuilt areas are smooth, the next step is to prepare the surface for painting. In cases where body work has been performed, these surfaces will have to be painted with a primer-surfacer. This is applied with a spray paint gun, and several coats are used to build up the area so that when it is sanded, no bare metal will be showing. To prepare the surface for paint, go over it with a No. 320 grit waterproof paper, and wet-sand the surface. Keep the paper wet by playing a water hose over the area being sanded. This will not only keep the paint from building up on the sandpaper, but will also prolong the life of the paper. If only spot repair is to be painted, the old paint must be sanded and featheredged. To featheredge a spot job, use a No. 240 grit waterproof paper on a rubber block. Sand the area until it is smooth and the edges of the old paint are featheredged. This is accompanied when you can see the different layers of primer and paint in a step formation. After the surface has been sanded and is smooth, it has to be cleaned of all sanding residue. Wipe the surface clean, using a clean cloth and an air gun to remove all traces of dirt and dust from crevices, etc. Wax particles must be removed by wiping the surface with a clean cloth dipped in a special solvent designed for wax removal. After wiping the surface, avoid touching it with your hands. Apply several coats of surface primer and alloy to dry. When dry, this will have to be wet-sanded and cleaned.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The first step in repairing the damaged metal illustrated below is to apply pressure

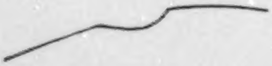


a. at point 'B' by hammering at point 'B'.
b. by hammering at point 'C'.
c. by hammering at point 'A'.
d. at point 'B' while hammering at point 'A'.

2. The second step in repairing the damaged metal illustrated in question 1 is

a. dinging, using light hammer blows.
b. dinging, using heavy hammer blows.
c. to apply pressure at point 'A'.
d. dinging, with hammer and dolly block.

3. The best method to use in removing the dent illustrated is



   a. dinging off the dolly.
   b. dinging on the dolly.
   c. dinging with only a hammer.
   d. dinging from the underside with a bumping hammer.

4. When shrinking sheet metal using an oxyacetylene torch, you should heat a spot of approximately ______ inch(s) in diameter in the center of the stretched area.

   a. 1/4
   b. 3/8
   c. 1
   d. 6

5. A small dent which is difficult to straighten should be filled with

   a. lead solder.
   b. fiberglass.
   c. plexiglas.
   d. liquid metal.

6. If a bar of solder has the numbers 40/60 on it, you would know that it is made of

   a. 40% lead and 60% zinc.
   b. 40% solder and 60% lead.
   c. 40% solder and 60% tin.
   d. 40% tin and 60% lead.

7. After you have featheredged a surface, it should be

   a. sandblasted and coated with lubricant.
   b. oiled.
   c. cleaned using a clean cloth and an airgun.
   d. primed.

8. List the four procedures (steps) for repairing body damage.

   a.
   b.
   c.
   d.

SUMMARY REVIEW

In this study unit you learned to identify the tools and procedures for repairing frames and body metals.

Answers to Study Unit #5 Exercises

Work Unit 5-1

1. c.
2. b.
3. d.
4. a. Hammers
    b. Metal dollies
    c. Body file
    d. Sanding Machine

Work Unit 5-2

1. a.
2. b.
3. a.
4. d.
5. d.

Work Unit 5-3

1. c.
2. d.
3. a.
4. b.
5. a.
6. d.
7. c.
8. a. Bumping and dinging
    b. Shrinking sheet metal
    c. Applying body fillers
    d. Finished-surface preparation

STUDY UNIT 6

WELDING SYMBOLS

STUDY UNIT OBJECTIVE: UPON SUCCESSFUL COMPLETION OF THIS STUDY UNIT, YOU WILL IDENTIFY THE WELDING SYMBOLS STANDARDIZED BY THE AMERICAN WELDING SOCIETY AND THE DEPARTMENT OF DEFENSE.

Work Unit 6-1. ELEMENTS OF A WELDING SYMBOL

IDENTIFY THE EIGHT WELDING SYMBOLS.

Welding symbols are the means by which information is placed on drawings for the guidance of welders and construction personnel. Special symbols showing the kinds of welds to be used have been standardized by the American Welding Society and the Department of Defense and apply to all types of welding. The symbols are placed on horizontal lines (reference lines) in open spaces on the drawing. The reference line of the welding symbol (fig 6-1) is used to designate the welding process to be used; its location, dimensions, extent, and contour; and other supplementary information. When necessary, a tail is attached to the reference line and used to provide specific notations. Arrowhead-tipped lines indicate the location of the welds. If the weld is to be on the arrow side of a joint, the symbol is placed on the lower side of the reference line; if the weld is to be made opposite the arrow, the symbol is placed above the reference line. If the weld is to be made at the place of installation, after the structure has been built in the shop, the field weld symbol is placed on the reference line. Welding symbols provide the means by which complete information is placed on drawings. The guide in figure 6-1 shows the relative location of all symbols that may be used to describe a weld. Often only parts of the system are used, but even then the information is conveyed in standard language.

The Army and Navy standard for welding symbols makes a distinction between the terms weld symbol and welding symbol. The assembled welding symbol consists of eight elements or any of these elements as is necessary. They are the reference line, arrow, basic weld symbol, dimensions and other data, supplementary symbols, tail, and the specification, process, or other reference. The location of the elements of a welding symbol with respect to each other is shown in figure 6-1. The weld symbol is that figure that is used to indicate the desired type of weld, as described in the following paragraph.

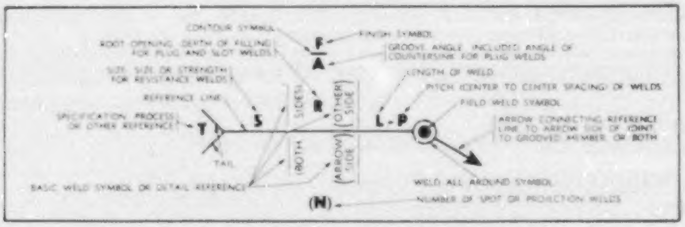
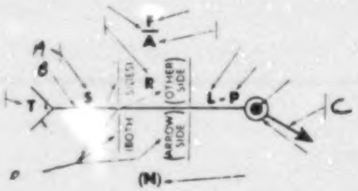

CONTOUR SYMBOL
ROOT OPENING, DEPTH OF FILLING (FOR PLUG AND SLOT WELDS)
SIZE, SIZE OR STRENGTH (FOR RESISTANCE WELDS)
REFERENCE LINE
SPECIFICATION, PROCESS, OR OTHER REFERENCE
T
TAIL
BASIC WELD SYMBOL OR DETAIL REFERENCE
S
F
A
R
(BOTH SIDES)
(ARROW SIDE)
(OTHER SIDE)
FINISH SYMBOL
GROOVE ANGLE, INCLUDED ANGLE OF COUNTERSINK FOR PLUG WELDS
LENGTH OF WELD
PITCH (CENTER TO CENTER SPACING) OF WELDS
FIELD WELD SYMBOL
L - P
ARROW CONNECTING REFERENCE LINE TO ARROW SIDE OF JOINT, TO GROOVED MEMBER, OR BOTH
WELD ALL AROUND SYMBOL
(N)
NUMBER OF SPOT OR PROJECTION WELDS

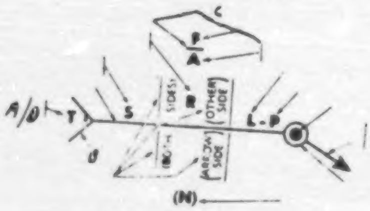
Fig 6-1. Standard location of elements on a welding symbol.

EXERCISE: Identify the symbols, 1-4, with their correct position in the diagram. Check your responses with those listed at the end of this study unit.

1. Reference line ______
2. Arrow ______
3. Basic weld symbol ______
4. Dimensions ______


F
A
A
B
S
R
(BOTH SIDES)
(ARROW SIDE)
(OTHER SIDE)
T
L - P
C
D
(N)

5. Supplementary symbols ____
6. Tail ____
7. Specification ____
8. Process ____


C
F
A
R
A/Ø
T
S
d
(BOTH SIDES)
(OTHER SIDE)
(ARROW SIDE)
L-P
(N)

Work Unit 6-2. BASIC WELD SYMBOLS

IDENTIFY THE WELDING SYMBOLS.

These weld symbols are used to indicate the welding process used in metal joining operations, whether the weld is localized or all around, and to indicate the contour of the welds (figs 6-2 through 6-4). Since no specific weld symbols have been devised or assigned for brazing or forge, thermit, induction, and flow welding processes, the tail of the welding symbol is used to designate which process is to be used, together with specifications, procedures, or other supplementary information required in making the welds.

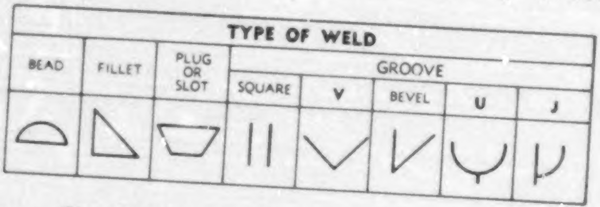

TYPE OF WELD
BEAD
FILLET
PLUG OR SLOT
GROOVE
SQUARE
V
BEVEL
U
J

Fig 6-2. Basic arc- and gas-weld symbols.

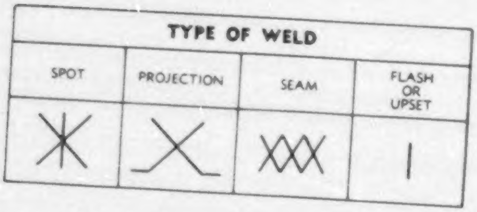

TYPE OF WELD
SPOT
PROJECTION
SEAM
FLASH OR UPSET

Fig 6-3. Basic resistance weld symbols.

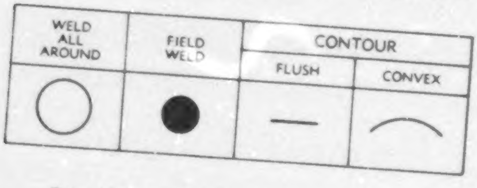

WELD ALL AROUND
FIELD WELD
CONTOUR
FLUSH
CONVEX

Fig 6-4. Supplementary symbols.

a. Location of weld symbols on welding reference line.

(1) Arrow side of the joint (fig 6-5). Welds on the arrow side of the joint are indicated by the weld symbol on the side of the reference line toward the reader.

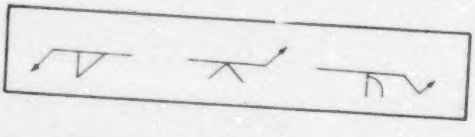


Fig 6-5. Weld symbol on the arrow side of the joint.

(2) Other side of the joint (fig 6-6). Welds on the other side of the joint are indicated by the weld symbol on the side of the reference line away from the reader.

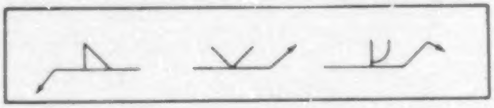
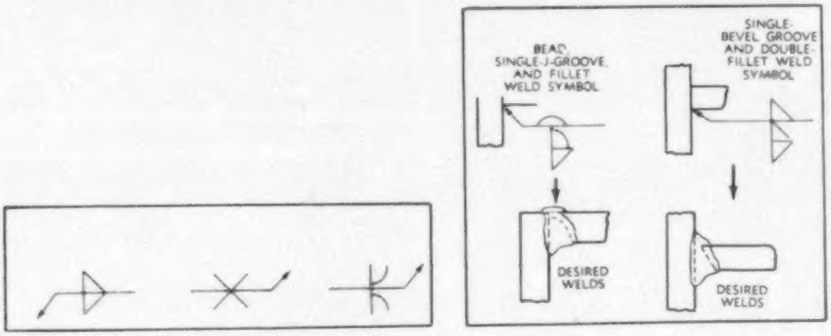


Fig 6-6. Weld symbol on the other side of the joint.

(3) Both sides of the joint (fig 6-7). Welds on both sides of the joint are indicated by the weld symbols on both sides of the reference line. In all of these cases concerning the reference line, the location of the weld symbol on the reference line denotes the position of the weld in reference to the line as shown in figure 6-7B. Also shown in B is a combination of more than one type of weld used on that particular joint.


BEAD, SINGLE-J-GROOVE, AND FILLET WELD SYMBOL
SINGLE-BEVEL GROOVE AND DOUBLE-FILLET WELD SYMBOL
DESIRED WELDS
DESIRED WELDS

A. Symbols on both sides.

B. Position of symbols on reference line.

Fig 6-7. Weld on both sides of the joint and position of the weld.

b. Fillet welding symbols.

(1) Size of the fillet weld (fig 6-8). The size of the fillet weld is shown at the left of the fillet weld symbol. If welds of the same size are on both sides of the joint, the weld symbol is placed as shown in A, but the weld size is shown on one side only. If the fillet welds on opposite sides of the joint differ in size, the sizes and the sides on which they are located are indicated as shown in figure 6-8. When the leg lengths of a fillet weld are not the same, the required measurement of the weld symbol is as shown in figure 6-8B.

(2) Length and spacing of fillet welds. The length of a fillet weld, when indicated on the welding symbol, is placed to the right of the weld symbol as shown in figure 6-8C. The dimension of an intermittent weld is indicated by showing the length of the weld to the right of the symbol, followed by the distance between centers of the weld. A chain intermittent weld is shown in figure 6-8C. The first figure indicates the length of the weld and the second figure indicates the spacing between the weld centers. When fillet welding extends the full distance between abrupt changes in the direction of the welding, no length dimensions are shown on the welding symbol (A and B, fig 6-8).

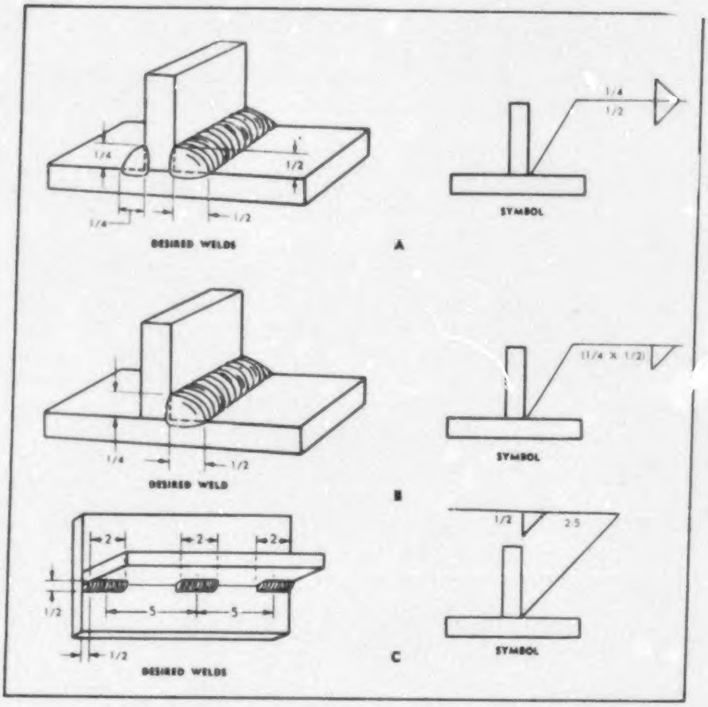


Fig 6-8. Fillet welds symbols.

(3) Fillet weld contours (fig 6-9). Fillet welds that are to be welded approximately flat-faced without any subsequent finishing operation are indicated by the addition of the flush-contour symbol (fig 6-4) to the weld symbol (fig 6-9A). Fillet welds that are made flat-faced by mechanical means are shown by the addition of the flush-contour symbol and the user's standard finish symbol to the weld symbol (fig 6-9B). Fillet welds that are to be finished to a convex contour by mechanical means are indicated by the addition of both the convex-contour symbol and the user's standard finish symbol to the weld symbol (fig 6-9C).

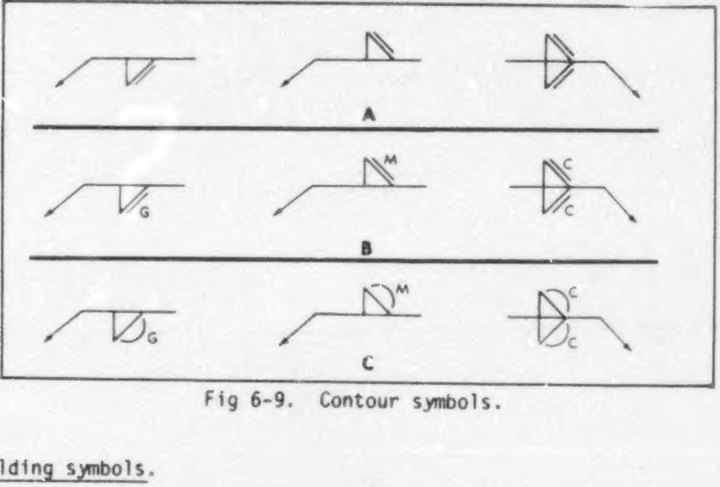


Fig 6-9. Contour symbols.

c. Groove welding symbols.

(1) General dimmensions of groove welds (fig 6-10). The size of a groove weld is shown on the same side of the reference line as the weld symbols (A, B, and C, Fig 6-10). When no general note governing the dimensions of groove welds is used and when both welds have the same dimensions, one or both may be dimensions, one or both may be dimensioned (D and E, fig 6-10). When the dimensions of the welds differ, both are dimensioned (F, fig 6-10). When both welds have dimensions governed by a note, neither is shown on the symbol.

(2) Size of groove welds. The size of a groove weld is the joint penetration (depth of chamfering plus the root penetration) and is shown to the left of the weld symbol (A, C, and F, fig 6-10). The size of the groove welds with no specified root penetration will be shown as indicated below.

(a) The size of the single groove and symmetrical double-groove welds which extend completely through the members being joined need not be shown on the welding symbol (A and B, fig 6-11).

(b) The size of groove welds which extend only partly through the member or members being joined will be shown on the welding symbol (C and D, fig 6-11).

The size of groove welds with specified root penetration will be indicated by showing both the depth of chamfering and the root penetration. The size is indicated on the left of the weld symbol by showing the depth of chamfering, a plus mark, and then the root penetration, in that order (E and F, fig 6-11).

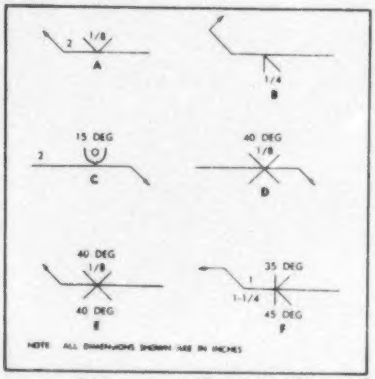

2
1/8
A
1/4
B
15 DEG
2
C
40 DEG
1/8
D
40 DEG
1/8
40 DEG
E
35 DEG
1
1-1/4
45 DEG
F
NOTE ALL DIMENSIONS SHOWN ARE IN INCHES

Fig 6-10. Groove welding symbols denoting weld size, groove size, and size of root opening.

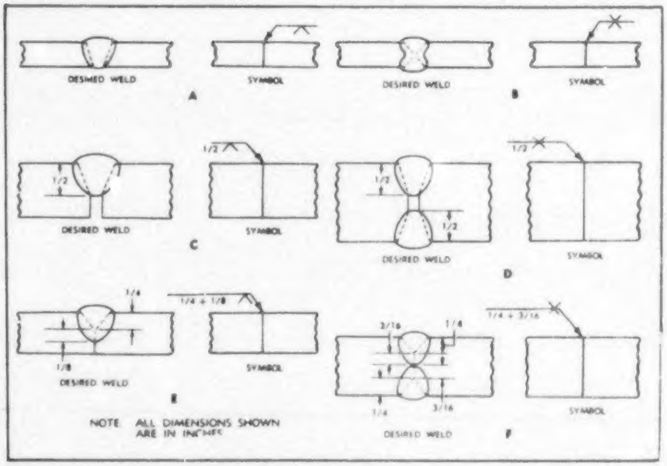

DESIRED WELD
SYMBOL
A
DESIRED WELD
SYMBOL
B
1/2
DESIRED WELD
1/2
SYMBOL
C
1/2
1/2
DESIRED WELD
1/2
SYMBOL
D
1/4
1/4 + 1/8
1/8
DESIRED WELD
SYMBOL
E
NOTE ALL DIMENSIONS SHOWN ARE IN INCHES
3/16
1/4
1/4 + 3/16
1/4
3/16
DESIRED WELD
SYMBOL
F

Fig 6-11. Size of groove welds with and without specified root penetration.

(3) Grooved dimensions. The root opening of the groove weld is shown inside the weld, as illustrated by the fraction 1/8 at A through E in figure 6-10. The groove angle of groove weld is shown in degrees of angle placed above or below the weld symbol (C, D, E, and F, fig 6-11). The welding symbols showing the symbols for the arrow side, other side, and both sides of groove welds of the U-groove types are illustrated figure 6-12. Similar symbols are used for bevel-, U-, and J-grooves.

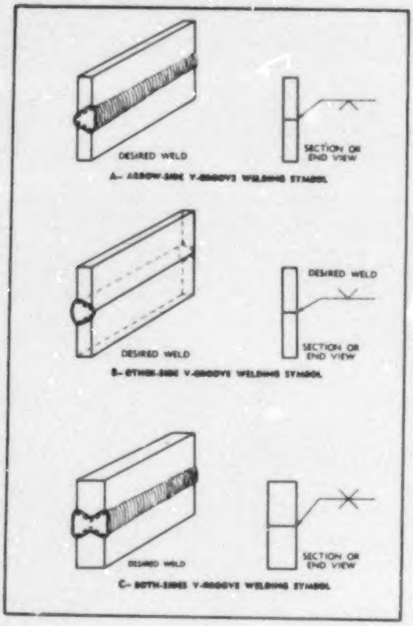
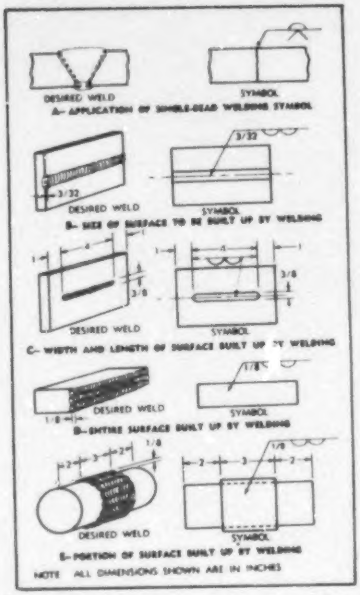

DESIRED WELD
SECTION OR END VIEW
A- ARROW-SIDE V-GROOVE WELDING SYMBOL
DESIRED WELD
DESIRED WELD
SECTION OR END VIEW
B- OTHER-SIDE V-GROOVE WELDING SYMBOL
DESIRED WELD
SECTION OR END VIEW
C- BOTH-SIDES V-GROOVE WELDING SYMBOL

Fig 6-12. V-groove welding symbols showing location of welds.

d. Bead welding symbols.

(1) Single-bead welding symbol (fig 6-13). The single-bead weld symbol is used to indicate the bead type of back or backing welds, of single-groove welds, and is shown by placing a single-beaded symbol on the side of the reference line opposite the groove weld symbol (fig 6-13A). The dimmensions of bead welds used in back or backing welds are not shown on the welding symbol.

(2) Dual-bead welding symbol. This symbol is used to indicate surfaces built up by welding (B through E, fig 6-13). The dual-beaded weld symbol does not indicate the welding of a joint and hence has no arrow side or other side significance. The symbol is shown on the side of the reference line toward the reader and the arrow points clearly to the surface on which the weld is to be deposited. The size of a surface buildup by welding is indicated by the height of the weld deposit to the left of the symbol (fig 6-13B). The width and length of the surface to be built up are indicated in figure 6-13C. When the entire area of a surface is to be built up by welding, no dimension other than height of deposit need be shown on the welding symbol (fig 6-13D). The buildup of a portion of the surface by welding is indicated in figure 6-13E.



A- APPLICATION OF SINGLE-BEAD WELDING SYMBOL

B- SIZE OF SURFACE TO BE BUILT UP BY WELDING

C- WIDTH AND LENGTH OF SURFACE BUILT UP BY WELDING

D- ENTIRE SURFACE BUILT UP BY WELDING

E- PORTION OF SURFACE BUILT UP BY WELDING

NOTE ALL DIMENSIONS SHOWN ARE IN INCHES

Fig 6-13. Application of bead weld symbols.

(3) Surface contour of back or backing weld. The contour, flush or convex, of back or backing welds is shown by using the contour symbol in the same manner as that required to show the contour of fillet welds (fig 6-9).

e. Plug- and slot-welding symbols.

(1) General. Neither the plug-weld symbols nor the slot-weld symbols are used to designate fillet welds in holes. The weld symbols for plug and slot welds are identical.

(2) Indication of plug and slot welds (fig 6-14). Plug or slot welds in the arrow-side member of a joint are indicated by the weld symbol on the reference line toward the reader (A and F, fig 6-14). Plug welds in the other-side member are indicated by the weld symbol on the side of the reference line away from the reader (fig 6-14B). Slots in the other-side member for slot weldings are indicated in the same manner.

(3) Plug welds.

(a) Size. The size of a plug weld is shown on the reference line to the left of the weld symbol (C and E, fig 6-14).

(b) Angle. The included angle of countersink appears as shown at C and E in figure 6-14.

(c) Depth of filling. Unless specified, the depth of filling plug and slot welds shall be complete. When the depth of filling is less than complete, the depth, in inches, is shown as illustrated in figure 6-14D.

(d) Spacing. The pitch (center-to-center spacing) of plug welds is shown in the reference line to the right of the weld symbol (C and E, fig 6-14).

(e) Surface contour. The contour of plug welds that are to be made approximately flush is indicated by the flush-contour symbol (fig 6-4) in the same manner as that required to show the contour of fillet welds (fig 6-9).

(4) Slot welds. The details of slot welds such as the length, width, spacing, included angle of countersink, orientation, and location, cannot be shown of the welding symbol. The information will be shown in the drawing or by a detail with a reference on the welding symbol, observing the usual location (fig 6-14G).

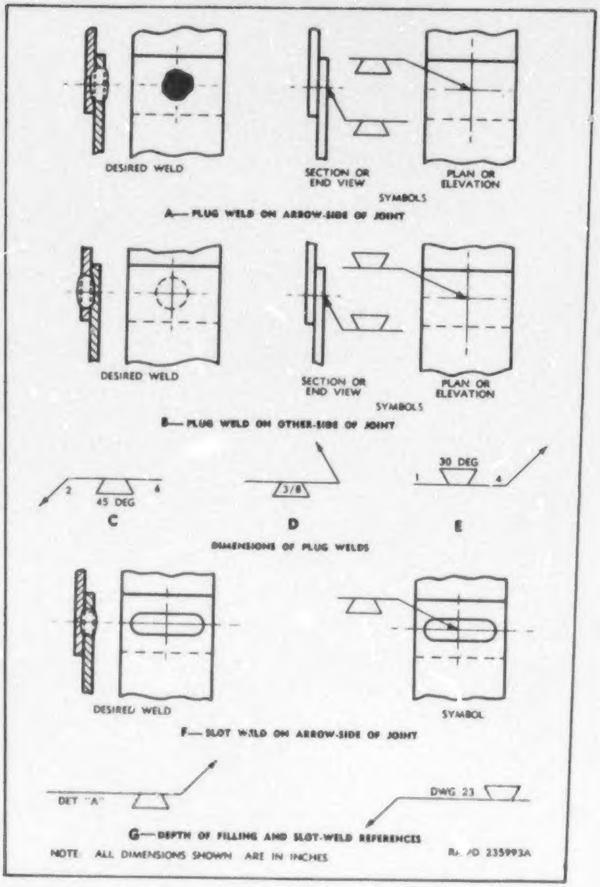

DESIRED WELD
SECTION OR END VIEW
PLAN OR ELEVATION
SYMBOLS
A—PLUG WELD ON ARROW-SIDE OF JOINT
DESIRED WELD
SECTION OR END VIEW
PLAN OR ELEVATION
SYMBOLS
B—PLUG WELD ON OTHER-SIDE OF JOINT
2
45 DEG
4
C
3/8
D
30 DEG
1
4
E
DIMENSIONS OF PLUG WELDS
DESIRED WELD
SYMBOL
F—SLOT WELD ON ARROW-SIDE OF JOINT
DET "A"
DWG 23
G—DEPTH OF FILLING AND SLOT-WELD REFERENCES
NOTE: ALL DIMENSIONS SHOWN ARE IN INCHES
R /D 235993A

Fig 6-14. Plug and slot welding symbols indicating location and dimensions.

f. Spot-welding symbols.

(1) General. Spot-welding symbols have no arrow or other-side significance, although supplementary symbols, such as flush contour, may have such significance. Spot-welding symbols are centered on the reference line of the welding symbol.

(2) Size. The size of a spot weld is its diameter expressed decimally in hundredths of an inch and is shown, with inch marks, on the reference line to the left of the welding symbol (fig 6-15A). Sometimes the strength of the weld is designated instead of its size.

(3) Strength. The strength of the spot weld is designated as the minimum acceptable shear strength in pounds per spot and is shown on the reference line to the left of the weld symbol (fig 6-15B).

(4) Spacing. The pitch (center-to-center spacing in inches) of spot welds is shown on the reference line to the right of the weld symbol (fig 6-15C).

(5) Extent. When spot welding extends less than the distance of the full length of the joint, the extent is dimensioned as shown in figure 6-15D.

(6) Number. When a definite number of spot welds is desired in a certain joint, the number is shown in parentheses, either above or below the weld symbol (fig 6-15E).

(7) Flush spot-welding joints. When the exposed surface of one member of a spot-welded joint is to be flush, that surface is indicated by adding the flush-contour symbol, observing the usual arrow or other side location significance (fig 6-15F).

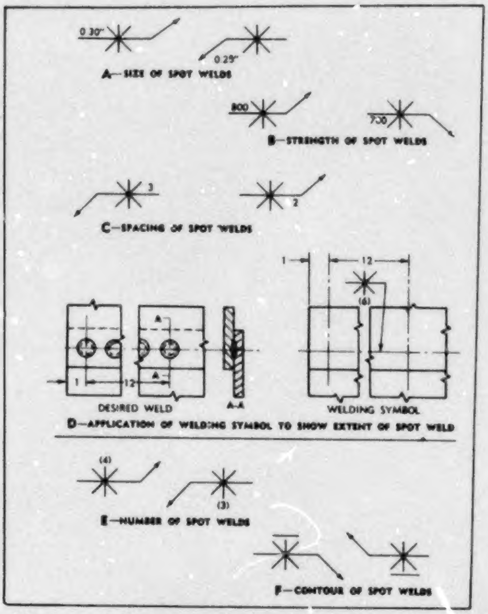

0.30"
0.25"
A—SIZE OF SPOT WELDS
800
700
B—STRENGTH OF SPOT WELDS
3
2
C—SPACING OF SPOT WELDS
1
12
(6)
A
1
12
A
DESIRED WELD
A-A
WELDING SYMBOL
D—APPLICATION OF WELDING SYMBOL TO SHOW EXTENT OF SPOT WELD
(4)
(3)
E—NUMBER OF SPOT WELDS
F—CONTOUR OF SPOT WELDS

Fig 6-15. Spot-welding symbols indicating size, strength, spacing, extent, and number of welds.

g. Seam-welding symbols.

(1) General. Seam-welding symbols have no arrow or other-side significance, although they can be used with the supplementary contour symbols which will have some significance. The seam-welding symbol is centered on the reference line of the welding symbol.

(2) Size (fig 6-16A). The size of the seam weld is designated as the width of the weld, expressed in hundredths of an inch, and is shown with inch marks to the left of the weld symbol. Sometimes it is expressed by specifying the strength of the seam.

(3) Strength. The strength of the seam is designated as the minimum acceptable shear strength in pounds per linear inch and is shown to the left of the weld symbol (fig 6-16B).

(4) Length. The length of the seam weld, when specified, is shown to the right of the weld symbol (fig 6-16C).

(5) Extent. When seam welding extends the full length of welding, between changes in direction of the weld, no length dimension is shown. However, when seam welding extends less than the full length of the joint, the extent is dimensioned as shown in figure 6-16D.

(6) Space. The center-to-center spacing of intermittent seam welding is shown to the right of the length dimension on the welding symbol reference line (fig 6-16E). When intermittent-seam welding is used between continuous seam welding, the symbol indicates the spaces equal to the pitch (center-to-center) minus the length of one increment, and is shown to the left at the end of the dimension length.

(7) Flush seam-welded joints (fig 6-16F). When the exposed surface of one member of a seam-welded joint is to be flush, that member is indicated by the addition of the flush-contour symbol.

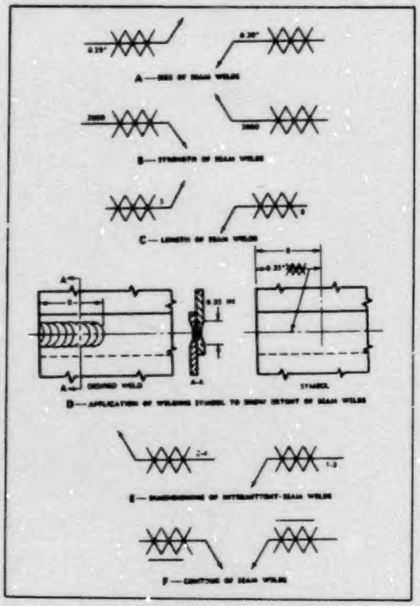


Fig 6-16. Seam-welding symbols indicating size, strength, length, extent, and contour of welds.

h. Projection welding symbols.

(1) Location. The location of embossments on the arrow-side member of a joint for projection welding are indicated by the weld symbol on the side of the welding symbol reference line toward the reader (fig 6-17A). Embossments on the other side of the joint are indicated by the weld symbol reference line away from the reader (fig 6-17B).

(2) Dimensions. Dimensions of the projection weld are shown on the side of the reference line as the weld symbol, and are dimensioned by either size or strength (not both) as described below.

(a) The size of the projection weld is designated as the diameter of the weld expressed decimally in hundredths of an inch, and is shown with inch marks to the left of the weld symbol (fig 6-17C).

(b) The strength of projection welds is designated as the minimum acceptable shear strength in pounds per weld and is also shown to the left of the weld symbol (fig 6-17D).

(3) Spacing (fig 6-17E). The pitch spacing in inches is shown to the right of the weld symbol.

(4) Number of welds. When a definite number of projection welds is desired, the number is shown in parentheses above or below the weld symbol (fig 6-17F).

(5) Extent of projection welds. When projection welds extend less than the distance between changes in the direction of welding or less than the full length of the weld joint, the extent is dimensioned as illustrated in figure 6-17G.

(6) Flush contour projection welded joints. When the exposed surface of one member of a projection joint is to be flush, the surface is indicated by the addition of the flush-contour symbol to the weld symbol, observing the required arrow side or other-side significance as shown in figure 6-17H.

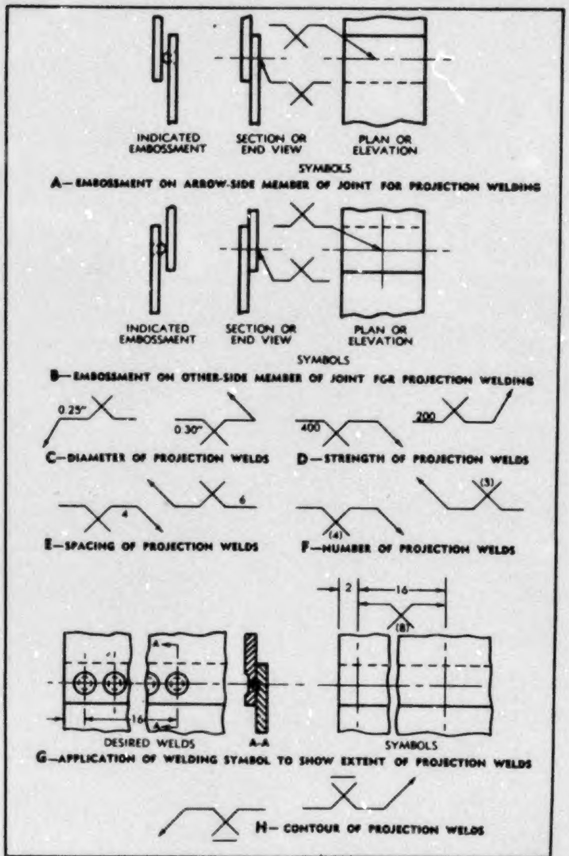
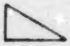
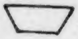

INDICATED EMBOSSMENT
SECTION OR END VIEW
PLAN OR ELEVATION
SYMBOLS
A—EMBOSSMENT ON ARROW-SIDE MEMBER OF JOINT FOR PROJECTION WELDING
INDICATED EMBOSSMENT
SECTION OR END VIEW
PLAN OR ELEVATION
SYMBOLS
B—EMBOSSMENT ON OTHER-SIDE MEMBER OF JOINT FOR PROJECTION WELDING
0.25"
0.30"
C—DIAMETER OF PROJECTION WELDS
400
200
D—STRENGTH OF PROJECTION WELDS
4
6
E—SPACING OF PROJECTION WELDS
(4)
(3)
F—NUMBER OF PROJECTION WELDS
2
16
(8)
A
16
A
DESIRED WELDS
A-A
SYMBOLS
G—APPLICATION OF WELDING SYMBOL TO SHOW EXTENT OF PROJECTION WELDS
H— CONTOUR OF PROJECTION WELDS

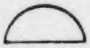
Fig 6-17. Projection welding symbols indicating location, dimension, spacing, number, extent, and contour of welds.

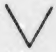
EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The symbol appearing on a reference line that indicates a bead weld is to be made is

a. 

c. 

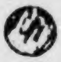
b. 

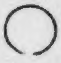
d. 

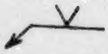
2. Projection and upset welds are signified by ________ symbols.

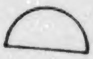
a. gas-welded
b. arc-welded
c. supplementary
d. resistance-welded

3. The symbol which is the supplementary symbol for a joint that is to be welded in the field is ____.

a. 

b. 

c. 

d. 

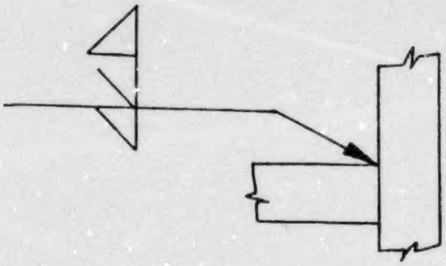
4. A joint that must be welded on both sides is identified by

a. the word "weld" on both sides of the reference line.
b. a weld symbol on only one side of the reference line.
c. weld symbols on each side of the reference line.
d. a "weld all around" symbol.

5. Flat-face fillet welds that require no additional weld finishing are indicated by the

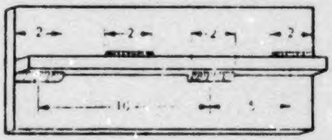
a. flush-contour symbol.	c. use of double arrow.
b. addition of a notation.	d. position of the reference line.

6. The symbol illustrated represents a combination of _________ welds.



a. bead, single-J-groove, and fillet
b. single-bevel groove and double-fillet
c. flush-contour
d. single-bevel groove and bead

Note: Questions 7-9 pertain to this diagram.



7. Identify the type of weld shown in the illustration.

a. dual bead	c. chain intermittent
b. staggered intermittent	d. surface buildup

8. The numeral 2 indicates the weld is

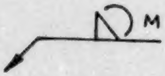
a. made in 2 passes.
b. 2 times the thickness of the metal.
c. 2 inches long.
d. made 2 times in 12 inches.

9. Identify a joint shown in the illustration.

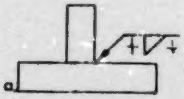
a. butt
b. tee
c. flush
d. overlap

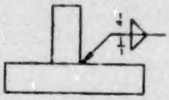
10. The symbol illustrated indicates the finished weld is to be

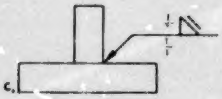
a. chipped.
b. flush.
c. graded.
d. machined.

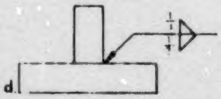


11. The symbol you should use to designate a tee joint with desired fillet welds of 1/4 inch on the left and 1/2 inch on the right is

a.


b.


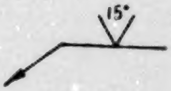
c.


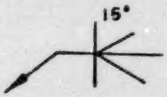
d.


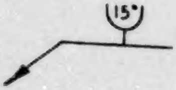
12. The formula, depth of chamfering plus the root penetration equals joint penetration, refers to the size of a _________ weld.

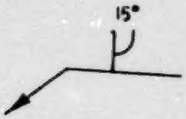
a. fillet
b. groove
c. plug
d. slot

13. A V-type groove weld with a groove angle of 15° is illustrated by symbol

a.


b.


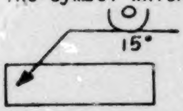
c.


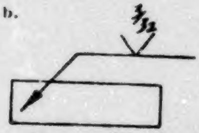
d.


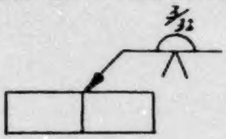
14. The entire surface buildup in bead welds is shown by

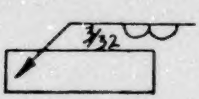
a. the height of the deposit.
b. the width and depth of the deposit.
c. the thickness and length of the deposit.
d. all of the above measurements.

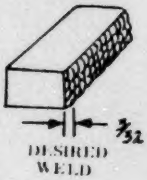
15. The symbol which represents the illustration at the right is

a.


b.


c.


d.




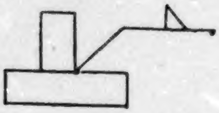
16. Plug weld sizes are shown on the _________ line.

a. projection
b. reference
c. center
d. datum

17. The weld symbol for a plug weld is the same as that used to identify a _________ weld.

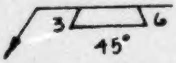
a. fillet
b. butt
c. groove
d. slot

18. The symbol illustrated is called a (an)



a. arrow-side fillet weld.
b. both-sides fillet weld, one joint.
c. other-side fillet weld.
d. both-sides fillet weld, two joints.

19. A ________ weld is called for by the symbol shown in this illustration.



a. plug
b. spot
c. groove
d. fillet

20. In the illustration for question 19, the numeral 3 indicates the

a. number of welds.
b. size of welds.
c. angle of weld.
d. spacing of weld.

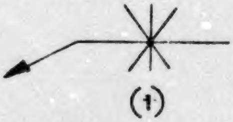
21. The size of spot welds is designated in

a. letter sizes.
b. fractions.
c. hundredths of an inch.
d. thousandths of an inch.

22. In parts fabricated by spot welding, the greatest concern is the spot's

a. tensile strength.
b. size.
c. appearance.
d. shear strength.

23. The symbol below illustrates the ________ of spot welds.



a. number
b. strength
c. size
d. spacing

24. The length of a seam weld is given when the

a. weld surface is convex.
b. weld surface is concave.
c. joint is longer than 6 inches.
d. weld is shorter than the joint.

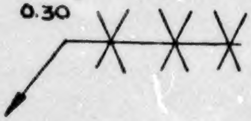
25. On a blueprint, the strength of a seam weld would be shown in

a. pounds per square inch.
b. pounds per square foot.
c. linear pounds per foot.
d. pounds per linear inch.

26. In intermittent-seam welds, the distance from center to center of the weld is called the

a. pitch.
b. protrusion.
c. projection.
d. embossment.

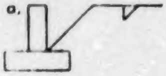
27. The symbol illustrated designates the ________ of a seam weld.



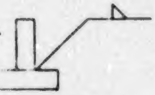
a. strength
b. size
c. length
d. contour

28. Identify the symbol that represents the desired weld illustrated.

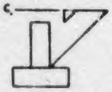
a.



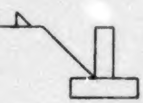
b.

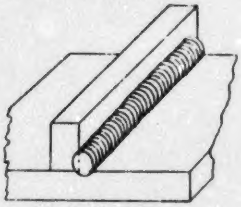


c.



d.





DESIRED WELD

SUMMARY REVIEW

In this study unit you have learned to identify the welding symbols, standardized by the American Welding Society and the Department of Defense.

Answers to Study Unit #6 Exercises

Work Unit 6-1

1. b.
2. c.
3. d.
4. a.
5. c.
6. b.
7. a.
8. d.

Work Unit 6-2

1. b.
2. d.
3. a.
4 c.
5. a.
6. b.
7. c.
8. c.
9. b.
10. d.
11. d.
12. b.
13. a.
14. a.
15. d.
16. b.
17. d.
18. c.
19. a.
20. b.
21. c.
22. d.
23. a.
24. d.
25. d.
26. a.
27. b.
28. a.

METALWORKING AND WELDING OPERATIONS

Review Lesson

Instructions: This review lesson is designed to aid you in preparing for your final exam. You should try to complete this lesson without the aid of reference materials, but If you do not know an answer, look it up and remember what it is. The enclosed answer sheet must be filled out according to the instructions on its reverse side and mailed to MCI using the envelope provided. The questions you miss will be listed with references on a feedback sheet (MCI-R69) which will be mailed to your commanding officer with your final exam. You should study the reference material for the questions you missed before taking the final exam.

A. Multiple Choice: Select the ONE answer that Best completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate circle.

Value: 1 point

1. The two most commonly used methods of welding are

   a. gas and TIG.
   b. MIG and electric.
   c. TIG and MIG.
   d. gas and electric.

2. To control and direct the heat on the edges of the metal to be welded and add a suitable filler material to the pool of molten metal is the principle duty in _________ welding.

   a. oxyacetylene
   b. MIG
   c. electric arc
   d. TIG

3. The characteristics of metal that enable it to resist deformation by external forces are called _________ properties.

   a. mechanical
   b. internal
   c. physical
   d. metal

4. Metal properties determined by chemical compositions which cannot be changed by heat-treatment are called _________ properties.

   a. mechanical
   b. internal
   c. physical
   d. metal

5. The four types of cast iron are gray, white, malleable, and

   a. pig.
   b. wrought.
   c. low carbon.
   d. tool.

6. All five types of plain carbon steels are _________ metals.

   a. alloy
   b. ferrous
   c. non-ferrous

7. The seven principal metals used in manufacturing steel are referred to as _________ metals.

   a. alloy
   b. ferrous
   c. non-ferrous

B. Match the nonferrous metals listed as "8" through "12" in column "1" with the correct characteristic, listed as "a" through "e" in column "2". Check your responses with those listed at the end of this study unit.

Column 1

8. Aluminum
9. Oxygen-bearing copper
10. Aluminum bronze
11. Copper-nickel
12. Magnesium

Column 2

a. Hardness, ductility, resist scaling and oxidation
b. Weldable, white metal, low melting point, machinable
c. Medium strength, ductile, tough, malleable
d. High strength, light weight, resists corrosion
e. Moderately hard, tough, ductile

C. Multiple Choice: Select the ONE answer that BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate circle.

13. A metal sheet with a classification number of 2340 indicates it is made of ________ steel with a content of _____% _________ and a carbon content of _____%.

a. nickel, 3% nickel, 40
b. nickel-chromium, 3% nickel and 4% chrome, 0
c. chromium, 34% chrome, 0

14. When studying the behavior of a metal you are performing the _________ test.

a. fracture
b. grinding wheel
c. torch
d. appearance

15. To develop ductility, induce toughness, and to aid machinability are three reasons for

a. identification of metal.
b. heat-treating metal.
c. manufacturing metal.
d. testing metal prior to welding.

16. The five most common forms of _________ metal are annealing, hardening, tempering, normalizing, and case hardening.

a. heat-treating
b. identifying
c. testing

17. Oxidation of the metal, during heat-treating is caused by

a. overheating.
b. underheating.
c. incorrect quenching.
d. improper annealing.

18. When quenching a metal part in water, the proper way is to

a. dip it and do not move it.
b. dip it and keep it moving.
c. place it gently on the bottom of the bath.
d. spray it gently with a hose.

19. At which point does the most radical changes occur in metal during heat-treatment?

a. Heat-treating point
b. Critical point
c. Tempering point
d. Melting point

20. Three changes take place when heat-treating metal; they are appearance, grain structure and grain

a. disintegration.
c. distortion.
c. shrinkage.
d. growth.

21. All of the below are types of heat-treating furnaces EXCEPT

a. electrically fired.
b. bath.
c. coal fired.
d. oil and gas fired.

22. The temperature of metal being heated is measured by a ________.

a. thermocoupling
b. dial indicator
c. thermostat
d. pyrometer

23. A lack of penatration would be an indication that you are welding with

a. a dirty or rusted welding surface.
b. too long an arc.
c. too short an arc.

24. When welding with the electrode connected to the ________ terminal and the work connected to the ________ terminal, you are welding in reverse polarity.

a. negative - negative
b. negative - positive
c. positive - positive
d. positive - negative

25. If, when you are welding in a corner or approaching an abrupt turn, magnetism makes the arc unstable and difficult to control, you are experiencing ________.

a. gas expansion
b. gravity
c. electromagnetic forces
d. arc blow

26. The principal parts of a groove and fillet weld are the root, toe and

a. fusion zone.
b. throat.
c. face.
d. leg.

27. Bead, fillet, tack, groove, and plug and slot are types of ________.

a. edges
b. symbols
c. joints
d. welds

D. Matching: Match the five types of joints in column 1, 28-32, with their correct uses, as listed in Column 2.

Value: 1 point each

Column 1

28. Butt
29. Corner
30. Edge
31. Tee
32. Lap

Column 2

a. To join two edges of sheet metal
b. To join two plates at 90° angle to each other
c. To join two edges or surfaces of two plates located approximately in the same geometric plane
d. To join two members located at right angles to each other
e. To join overlapping plates

E. Multiple Choice: Select the ONE answer which BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate circle.

Value: 1 point each

33. The best type of weld to use when building up a surface is a

a. slot.
b. tack.
c. bead.
d. fillet.

34. A clear cover glass is placed over the protective filter lens to

a. filter infrared rays.
b. reduced glare.
c. protect the colored lens.
d. keeps the colored lens clean.

35. You should not use a color filter lens used in welding helmets that varies more than __________ shades from the prescribed shade number.

a. 2
b. 4
c. 6
d. 7

36. The material used to make welders gloves is

a. leather.
b. nylon.
c. pig skin.
d. cotton.

37. To prevent flickering reflections, an area where welding is being done should be painted

a. flat black.
b. dark green.
c. olive drab.
d. dark orange.

38. The letter "E", in an electrode classification number, stands for

a. everything rod.
b. electrode.
c. evaporating rod.
d. electric.

39. The second and third digits of an electrode classification number stand for

a. size of rods.
b. size of bead it will produce.
c. tensile strength.
d. amount of rods per pound.

40. The fourth digit of an electrode classification number stands for

a. the amount of rods per pound times one thousand.
b. the type of rod.
c. tensile strength.
d. the position in which it may be applied.

41. A rectifier-type welding machine produces __________ current.

a. polar
b. a. c.
c. d. c.
d. either a. c. or d. c.

42. The LM-62 welder is a

a. gas engine driven, self contained d. c. welder.
b. diesel engine driven, self contained d. c. welder.
c. gas engine driven, self-contained a. c. welder.
d. diesel engine driven, self-contained a. c. welder.

43. The starter on the LM-62 welder should be allowed to cool for at least __________ after __________ of cranking.

a. 30 seconds - 2 minutes
b. 45 seconds - 1 minute
c. 1 minute - 45 seconds
d. 2 minutes - 30 seconds

44. The __________ gage should be checked after running the LM-62 welder for __________ to __________ seconds.

a. fuel pressure/30-40
b. ammeter/20-30
c. oil pressure/10-20
d. water temperature/0-10

45. Proper polarity is best described by a ________ sound.

a. low hissing
b. loud drumming
c. high hissing
d. sharp crackling

46. There should be approximately __________ or an inch penetration into the base metal for a good bead weld.

a. 3/16
b. 1/4
c. 1/8
d. 1/16

47. The purpose of quenching plates clamped parallel to the seam when welding sheet metal is to

a. hold the metal in place for welding.
b. serve as deflectors for sparks.
c. acts as a backup plate for reinforcement.
d. decrease expansion and contraction by absorbing the heat.

48. An essential part of any job is awareness of possible hazards, knowledge of ways to avoid or control dangerous conditions and

a. safety rails.
b. safety consciousness.
c. the position used.
d. type of metal.

49. An acetylene cylinder is a _________ color.

a. green
b. yellow
c. gray
d. gray w/ white band

50. The narrow slit formed when steel has been cut with a torch is a _________.

a. line cut
b. cut weld
c. kerf
d. opening

51. When cutting mild steel, 1 inch thick, use size tip ________.

a. 6
b. 4
c. 2
d. 0

52. The correct method to use when cleaning a cutting torch tip is to use the proper size tip cleaner and

a. then use the next size larger tip cleaner.
b. then use a fine piece of wire and rotate.
c. then rotate the cleaner.
d. push it into the oriface.

53. An oxygen cylinder is a _________ color.

a. green
b. yellow
c. gray
d. gray with a white band

54. A high pressure gauge which is graduated from _________ to _________ psi on the inlet side of the regulator is the oxygen gauge.

a. 0-1,000
b. 0-2,500
c. 0-3,000
d. 0-5,000

55. A high pressure gauge which is graduated from _________ to _________ on the inlet side of the regulator is the acetylene gauge.

a. 0-1,000 psi
b. 0-2,000 psi
c. 0-220 cubic feet
d. 0-2,500 cubic feet

56. Two based alloys used in brazing are _________ and _________.

a. Aluminum - lead
b. Magnesium - silver
c. Lead - copper
d. Copper - silver

57. When the rod is kept ahead of the welding tip, the technique of welding is called _________.

a. backhand
b. underhand
c. forehand
d. overhand

58. When the tip is kept ahead of the rod the welding technique is called _________.

a. backhand
b. underhand
c. forehand
d. overhand

59. If you are cutting metal too slowly with a torch, it will cause

a. the preheat flame to melt the edges.
b. a clean, sharp cut.
c. an enlarged kerf.
d. too much oxygen penetration.

60. To start a cut in the middle of a piece of metal you must

a. tilt the torch to 45° angle to preheat the metal and open the high pressure value slowly.
b. raise the torch slightly for slower heating and open the high pressure value quickly.
c. lower the torch tip for faster heating and open the high pressure value quickly.
d. keep the torch tip at a 90° angle and open the high pressure value quickly.

61. To cut a pipe with a torch you should

a. move the torch around the pipe.
b. rotate the pipe and hold the torch still.
c. move the torch first down one side, then down the other.
d. move the torch, at a 45° angle, completely around the pipe.

62. When checking a cylinder for leaks, you should

a. use a leak detector.
b. use a soapy water solution.
c. use a flame.
d. smell for fumes.

63. You should use _________ type goggles when gas welding at eye level or above.

a. heavy plastic
b. rigid-bridge
c. eye cup
d. clear

64. Acetylene working pressure in excess of _________ psi must be avoided.

a. 50
b. 40
c. 20
d. 15

65. A gas leak between the regulator seat and the nozzle is caused by a _________.

a. broken gauge tube
b. leaking torch valve
c. cracked, worn, or dirty valve seat
d. defective gauge

66. If you receive a shock while operating the LM-62 welder, the problem is

a. the welder is not properly grounded.
b. the electrode holder spring is weak.
c. the commutor is dirty.
d. the polarity is wrong.

67. The dynamotor starts but rotates in the wrong direction the problem is _________.

a. dynamotor switch is defective
b. d.c. ammeter is defective
c. external powerlines are incorrectly connected
d. drive belts are defective or worn out

68. You must make sure the end of the electrode wire extends approximately _________ inches beyond the end of the nozzle of the SWM-9 torch before starting to weld.

a. 2 1/2
b. 2
b. 1
c. 1/2

69. Hawks-bill, trojan, aviation, and _________ are the four types of snips.

a. straight
b. circle
c. flat
d. rotary

70. The name of the snips used for several types of cutting is _________.

a. aviation
b. hawks-bill
b. trojan
d. circle

71. Throatless, handbench, and _________ are the three types of shears.

a. squaring
b. manual
c. straight
d. power

72. The cornice brake machine is designed for

a. shaping small strips of sheet metal.
b. bending small pieces of cast iron.
c. bending large sheets of metal.
d. cutting irregular shapes.

73. The machine used for burring a disk is a _________ machine.

a. grinding
b. rotary
c. slip-roll forming
d. deep-throat bending

74. The allowance for a lap seam which is to be riveted with 1/8 in. rivets is _________ inch.

a. 1/8
b. 1/4
c. 1/2
d. 3/4

75. In making a corner lap seam is to riveted, your allowance for clearance should be

a. 4 times the diameter plus 1/16 inch.
b. 2 1/2 times rivet diameter.
c. 4 times rivet diameter.
d. 1/2 the lap width.

76. If a 3/8 in. grooved seam is specified, your allowance on each edge would be _________ inch.

a. 3/8
b. 9/16
c. 3/4
d. 1 1/8

77. The type of seam used for the construction of a cylinder is a _______________ seam.

a. grooved
b. Pittsburgh lock
c. plain lap
d. off set lap

78. With reference to the pocket depth on the Pittsburgh lock seam, the width of the flanged edge must be

a. more.
b. less.
c. the same.
d. twice the pocket depth.

79. The four basic types of handtools used in repairing body damage are

a. bucking bars, chisels, hammers, and arc welder.
b. hammers, arc-welder, metal dollies, and sanding machine.
c. hammers, bucking bars, chisels, body files.
d. hammers, metal dollies, sanding machines, body files.

80. In the diagram below, the reinforcement plate should be welded at

a. 1, 2, 3, and 4.
b. 3 and 4.
c. 2 and 4.
d. 1 and 2.

81. When found on a bar or "stick" of solder, the numbers 30/70 indicate

a. the manufacturer's code.
b. 30% iron and 70% zinc content.
c. 30 to 70% lead content.
d. 30% tin and 70% lead content.

82. A joint which is to be welded on both sides is indicated

a. weld symbols on each side of the reference line.
b. one weld symbol underlined.
c. the word "weld" written on the metal.
d. color code.

83. The symbol for a slot weld is the same as that used for a _________ weld.

a. plug
b. fillet
c. groove
d. butt

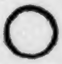
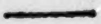
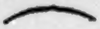
84. Plug weld sizes are shown on the _________ line.

a. datum
b. projection
c. reference
d. bottom

85. In the drawing below, a _________ weld is shown.

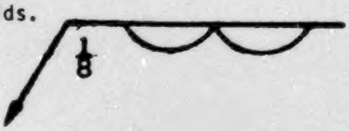
a. groove bevel
b. plug or slot
c. square
d. bead

86. In the supplementary symbols illustrated below, _________ indicated a field weld.

a. 
b. 
c.
d. 

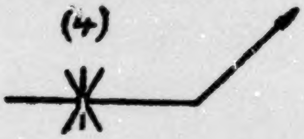
87. Illustrated below is a dual-bead welding symbol which is used to indicate

a. surface built up by welding.
b. the welding of a joint that has been spot welded.
c. single backing welds.
d. double backing welds.



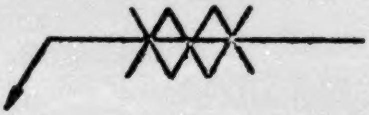
88. In the drawing below, _________ is illustrated.

a. the spacing of spot welds in inches
b. the width of a spot weld in tenths of an inch
c. the number of spot welds desired at a certin joint
d. the shear strength of the spotweld in thousands of pounds

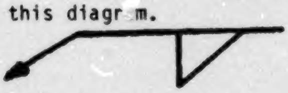


89. The welding symbol illustrated below indicates

a. V-groove.
b. seam weld.
c. projection weld.
d. slotweld.



Note: Questions 90 and 91 pertain to this diagram.



90. The weld symbol shown is a _________.

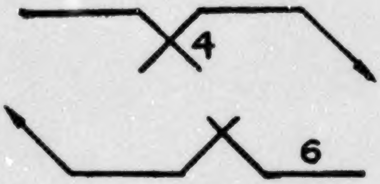
- a. groove bevel
- b. bead
- c. slot
- d. V

91. This weld should be made on

- a. arrow side of the joint.
- b. the side of the joint away from the reader.
- c. any side of the joint with this symbol.
- d. opposite side of the joint.

92. The symbols below are projection weld symbols. The numbers indicate

- a. the 4th and 6th weld to be completed.
- b. the shear strength in thousands of pounds.
- c. the pitch spacing in inches.
- d. the pitch spacing in feet.



ISD-1

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The Marine Corps Institute would appreciate your help in improving the course you have just completed. If you would take a few minutes to complete the following survey, we would have valuable information to help us improve this course. Your answers will be kept confidential and will in no way affect your grade.

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Name (Optional) ____________________

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1. Did you find inaccurate or outdated information in this course? ☐ Yes ☐ No

   List the areas you found inaccurate or out of date. Give page or paragraph if possible.

2. How long did it take you to finish the course?

   ☐ 1-5 hours ☐ 11-15 hours ☐ More than 20 hours
   ☐ 6-10 hours ☐ 16-20 hours

3. Were the procedures taught in this course understandable and useful? ☐ Yes ☐ No

   If "No," how could they be improved? ____________________

4. How much of the material taught in this course can you apply to your job?

   ☐ Almost all ☐ Very little ☐ None
   ☐ More than half ☐ Less than half

5. Did you have trouble reading or understanding the material in this course? ☐ Yes ☐ No

   If "Yes,", explain____________________

6. Were the illustrations in this course helpful? ☐ Yes ☐ No

   If "No," how could they be improved?____________________

7. Put an "X" in a box on the scale below to show how well you feel the lessons and the course materials prepared you for the final examination. (On this scale "10" indicates that the material prepared you very well, a "5" indicates adequate preparation, and a "1" indicates very poor preparation.)

Very Poor				Adequate					Very Well
1	2	3	4	5	6	7	8	9	10

8. If you asked MCI for help, were the answers to your questions helpful?

   ☐ Yes ☐ No ☐ No questions sent to MCI

9. Please list below any suggestions you may have to improve this course. Try to be specific; give page or paragraph numbers. (You may also use the space on the back or attach additional sheets.)

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